The Rapid Update Cycle
Part II: Verification and Evaluation

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1. INTRODUCTION

In the mid 1980's, a government-sponsored task force on aviation weather forecasting was formed (Aviation Weather Forecasting Task Force 1986). The final report of that task force stated, "Aviation's most crucial need is for accurate weather analyses and forecasts out to about six hours..." It stressed the point that "...the rapid and frequent distribution of these [analyses and short-term forecasts] is imperative for their benefit to be fully realized." It also recognized that the recent increases in asynoptic data from sources such as automated aircraft reports and wind profilers would allow such analyses and forecasts to be produced by numerical modeling. The report combined all these thoughts into the task force's Recommendation 10: "Develop a four-dimensional data assimilation system capable of incorporating data from automated aircraft reports and other new observing systems and producing frequently updated analyses and short-term forecasts for domestic aviation." The Rapid Update Cycle (RUC) was born of, and designed specifically in response to, that recommendation.

The RUC is an analysis/forecast data assimilation system developed by the Forecast Systems Laboratory (FSL) of NOAA's Environmental Research Laboratories (Benjamin, et al. 1994a). The version running at FSL is called the Mesoscale Analysis and Prediction System (MAPS). The RUC was implemented operationally at the National Center for Environmental Prediction (NCEP) at 1200 UTC, on September 27, 1994. It enjoys a unique position at NCEP, providing analyses and forecasts at frequent intervals in real time. The upper-air component of the RUC consists of an analysis and forecast out to 12 hours every 3 hours (8 times per day). A surface component produces analyses of nine surface variables every hour. The horizontal domain is a 60-km resolution grid covering the continental United States. The RUC's vertical structure is a unique hybrid of sigma and isentropic coordinates. Most of its 25 levels are isentropic except for layers in the lowest 1-2 km of the atmosphere where terrain-following coordinates are used. The two types of surfaces do not intersect but change smoothly from one to another.

As part of NCEP's implementation procedure, subjective and objective evaluations were performed. This Technical Procedures Bulletin (TPB) reports on some of the findings of these evaluations. A previous TPB (Benjamin et al. 1994b) described the analysis procedure and forecast model.

2. THE OBJECTIVE EVALUATION

The objective evaluations consisted of verification against observed data. A simple bi-linear interpolation was used to obtain an analyzed or forecast value at the observation's location from model fields on mandatory pressure levels. Separate comparisons were made against rawinsondes and a combined dataset of profiler and automated aircraft reports. Separate mean and standard deviation error statistics were computed from temperature and moisture variables. It should be remembered that both of these quantities contribute to the total error of the forecasts. Mean speed differences and RMS vector differences were computed to represent the errors in the wind forecasts. In addition to the comparisons with data, comparisons with other NCEP regional operational models are shown. We provide them as an additional measure of the RUC's performance. However, it should be remembered that the RUC did not replace any operational model at NCEP, but rather assumed its own unique position, providing frequent, shortterm, mesoscale forecasts as rapidly as possible.

The objective verifications were computed during the period of April 8 - May 7, 1994. During that period, only observation times for which all models were available were used to compute the statistics. This turned out to be 56 out of the 60 0000 and 1200 UTC observation times.

2.1 Temperature

Fig. 1 presents bias and standard deviation computations verifying temperature for the RUC (a) analysis, (b) 3-h forecast, and (c) 12-h forecast against rawinsonde data. Also included on the figure for comparison are the same calculations from NCEP's Early Eta run (ETAX) and NCEP's Regional Analysis and Forecast System (RAFS) which uses the Nested Grid Model (NGM).

Fig. la illustrates the degree to which the RUC analysis draws for the rawinsonde temperature data. The standard deviation of its difference with the data is one degree C or less at all mandatory pressure levels except the lowest and highest. The bias of the RUC's analysis, as well as the Eta's and RAFS's, is also very small.

Fig. 1b presents the bias and standard deviation of the difference between rawinsonde measurements and 3 hour forecasts from the RUC and NCEP's Regional Data Assimilation System (RDAS). A 3-h forecast valid at 0000 and 1200 UTC is not available from the RAFS. The RDAS uses the same analysis and forecast model as the RAFS to produce analyses and 3-h forecasts every 3 hours with the purpose of providing the best possible guess to the RAFS at 0000 and 1200 UTC. Since the RUC also uses its own 3-h forecast as its guess, Fig. 1 b is a comparison of the first guesses of the two systems, as well as a demonstration of the level of the error in the RUC's short range forecasts.

'Fig. 1c shows that the error in the temperature forecasts at 12 hours for the RUC is comparable to the temperature error in the Eta at almost all levels. The error in the RAFS is slightly higher above 400 mb.

All of the plots of the temperature biases in (a), (b), and (c) show a small positive or warm bias at all levels with the minimum occurring at 400 and 500 mb.

2.2 Winds

Fig. 2 presents wind speed bias and the RMS vector wind error computed from rawinsonde winds and the RUC (a) analysis, (b) 3-h forecast, and (c) 12-h forecast. Again, identical computations made from the Eta and the RAFS are included for comparison. The graphs of the wind speed bias in (a), (b), and (c) all show very small mostly negative biases for all the models. The results of the RMS vector wind error calculations, which include error contributed by both wind components, illustrate a reasonably close fit to the data at analysis time (from about 3 m/s at 1000 mb to about 4 m/s at 200 mb) for the RUC and 3-h forecast errors ranging from less than 4 m/s at 1000 mb to just over 6 m/s at jet level. In comparison, at jet level, the RDAS at 3 hours has vector wind errors almost 2 m/s greater. At 12 hours, the vector wind errors of the RUC and the RAFS are more comparable and at least above 400 mb, the Eta vector wind error is lower.

One reason RUC forecasts do not appear to verify as well at 12 hours comes from the fact that the RUC obtains its lateral boundary conditions from the NGM. RUC forecasts out to 12 hours from any RUC cycle need boundary conditions valid up to 12 hours after its initial time. For all the RUC cycles except 0000 and 1200 UTC, these are easily obtained from the most recent run of the NGM (RAFS). However, since the 0000 and 1200 UTC RUC completes its run earlier than the 0000 and 1200 UTC NGM, the 0000 and 1200 UTC RUC must use NGM forecasts from the previous (12 hours older) cycle. This means that for the 0000 and 1200 UTC cycles of the RUC, the 12-h RUC forecast must use a 24-h forecast for its boundary conditions. The effect of the older boundary conditions is illustrated in Fig. 3, which compares the RMS vector wind error computed from 0000 and 1200 UTC rawinsonde wind observations and RUC analyses, 3-, 6-, 9- and 12- h forecasts valid at those same times. These verifications were calculated during the period of April 1-30, 1994. Because they all verify at 0000 and 1200 UTC, all of the RUC forecasts shown in Fig. 3, except the 12-hour, use 12-h forecasts from the NGM for their boundary conditions. In contrast, the 12-h RUC forecast valid at 0000 and 1200 UTC uses a 24-h forecast for boundary conditions because, as noted above, the newest 0000 or 1200 UTC NGM run is not available until after the 0000 or 1200 UTC RUC finishes. From the figure, it is obvious that the greatest increase in error occurs between the 9- and 12-h forecasts, thus isolating the effect of the older boundary conditions.

Wind speed biases and RMS vector wind errors were also computed from model output and an observation dataset made from combining profiler and aircraft winds. These calculations are presented in Fig. 4 for (a) analysis, (b) 3-h forecasts, and (c) 12-h forecasts. There were about 26 wind profiler stations reporting regularly during this 30-day period, all located near the center of the U.S. Wind reports from aircraft added to those reports resulted in statistics calculated from a total of roughly 10,000 reports at jet levels. Statistics computed from 1000 mb and 100 mb were omitted from the graphs because of the low counts at those levels. All of the statistics in Fig. 4 used data with valid times of 0000 and 1200 UTC, allowing them to be directly compared with the corresponding values computed from rawinsondes in Fig. 2. These verifications tell a story similar to that of the verifications with rawinsonde data. The speed biases are mostly negative and small, although the verifications in Fig. 4 reach a peak negative bias at 250 mb where there is a maximum of aircraft data. This negative peak is not seen in verifications with rawinsonde data (Fig. 2). At 3 hours, the vector wind error of the RUC is up to 1 m/s lower than the RDAS. At 12 hours, the difference with the RAFS is less. The RUC error is slightly greater than that from the 12-h Eta forecast at 250 mb and above but slightly lower from 700-300 mb.

Since profiler and aircraft winds are available every hour, they were used to verify 6-h wind forecasts run from 0000 and 1200 UTC and valid at 0600 and 1800 UTC. These verifications can be seen in Fig. 5. The wind speed bias continues to be small. The RMS vector wind error of the RUC is comparable to or slightly greater than the Eta and RAFS at 300 mb and below (where profiler observations dominate) and lower than the other two regional models at 250 and 200 mb (where there are many more aircraft reports).

2.3 Moisture

Fig. 6 contains computations of the bias and standard deviation of differences between rawinsonde observations of relative humidity and the RUC (a) analysis, (b) 3-h forecast, and (c) 12-h forecast. The most striking characteristic of these graphs is the dry bias below 500 mb exhibited by the RUC at each time period. Also interesting is the drier nature of the RUC with respect to the Eta and the RAFS. These statistics, combined with the comments and opinions offered by participants in the subjective evaluation, led the developers at FSL to examine the coding pertaining to moisture manipulation in the RUC analysis and forecast model (Benjamin, personal communication). An error was discovered involving moisture variable transformations. This error was corrected and new objective statistics of relative humidity were generated for the 30-day period from July 17 August 15, 1994. Graphs corresponding to Fig. 6 for this new period are shown in Fig. 7. Disappointingly, the biases were still large and dry above 850 mb and the contrast with the other NCEP regional models was still apparent.

To confirm that the correction to the code was indeed made properly, a comparison was made with relative humidity biases from the MAPS run at FSL during the same two periods (April 1-30, 1994 and July 17- August 15, 1994). During the April time period, the two systems differed only in the data available to them since they run at two different sites. During the July-August time period, beside the data difference, the two systems differed in that the RUC had the correction to the moisture variable transformation and the MAPS did not. A comparison of relative humidity biases at some pressure levels for both time periods is presented in Table 1. The RUC biases are smaller relative to the MAPS biases during the July-August period. Therefore, there is some improvement apparent from the correction, although overall, the low-level biases remain dry. The cause remains under investigation. Fig. 6, as well as Fig. 7, show that the standard deviation of relative humidity error for the RUC is slightly smaller than the other regional models.

2.4 Summary of objective results

Three main conclusions were highlighted by the statistics. The first is that the RUC produces a credible analysis, or in other words, it draws closely for the data at analysis time. This was illustrated by the graphs of the standard deviation of temperature and the RMS vector wind error at analysis time. The RMS vector wind error is very close to the values specified as the observational error of rawinsonde winds.

The second conclusion derived from examining the statistics is that there are few gross biases present. The lone exception is the dry bias described above. The biases for the temperature and winds remain small at 3 hours and also all the way out to 12 hours.

The third conclusion is that the RUC produces what it was specifically designed for: good short-range forecasts. This can be seen from the 3-h forecast error presented in part (b) of Figs. 1, 2, 4, and 5. At 12 hours (part (c)), the objective statistics from the RUC were comparable or slightly worse than the other NCEP regional models.

3. **THE SUBJECTIVE EVALUATION**

The subjective evaluations of the RUC were performed by forecasters at NCEP's Aviation Weather Center (AWC) in Kansas City, the NCEP's Hydrometeorological Prediction Center (HPC) in Camp Springs, and the Spaceflight Meteorology Group (SMG) in Houston. They were conducted during the months of March and April 1994. The goal of the evaluation was to determine if the more frequently updated RUC forecasts were an improvement over the other forecasts available at the NCEP. Another aspect of the subjective evaluation was to determine if the RUC is a useful tool for diagnosis and short-range forecasting.

The primary objective of the first two groups was to subjectively determine if the forecasts from the RUC provided improvement of upper level wind forecasts, over other available models. Their specific strategy to achieve this goal was to compare the RUC performance with the 12-h forecast from NCEP's Eta Model (Black, et al. 1993). They felt that since the purpose of the RUC is to provide updated forecasts, it was fair and proper to compare shorter term forecasts from the RUC with 12-h forecasts from the Eta. The SMG evaluated the RUC as a supplementary tool to other models for low level forecasting.

3.1 The evaluation by AWC

At AWC, the evaluation period was from March 15 -April 15, 1994. Evaluation times were at 0000 and 1200 UTC only. The forecasts that were evaluated were the 12-h Eta, and the 3-, 6-, 9-, and 12-h RUC. All forecasts valid at 0000 and 1200 UTC were compared subjectively to the analysis produced by NCEP's Aviation Run, which has a data cutoff time of 3 hours. An evaluation form, filled out by the forecaster on duty, required the forecasts to be both scored and ranked. An example of a filled out form is shown in Fig. 8. All forecasts had to be available in order for the evaluation to occur. The AWC forecasters assigned a score for the quality of each of the forecasts, ranging from 1 for excellent to 3 for poor. The forecasts were then compared with the others and ranked 1 (best) to 5 (worst).

AWC has three forecast desks corresponding to the FAA areas: West, Central, and East. Each desk did the evaluation only for its section of the country. All desks performed evaluations for the 250-mb jets. In addition, the West Desk looked at 500-mb parameters, the Central Desk, 700-mb parameters, and the East Desk, 850-mb parameters.

The fields that were evaluated included:

1. 250-mb polar and subtropical jet speed and position
2. 500-, 700-, and 850-mb max wind speed and position
3. 500-, 700-, and 850-mb temperature (0 to -20C)
4. 500-, 700-, and 850-mb dewpoint depression (5C or less)

The results of the evaluation are shown in Tables 2 and 3. Fig. 9 shows that the average scores for both the polar and subtropical jet stream speed and position were better for the 9-, 6-, and 3-h RUC forecasts than they were for the 12-h Eta, with, as one might expect, the 3-h RUC forecasts scoring the best. These scores imply that the off-synoptic data (Aircraft Communications Addressing and Reporting System (ACARS), wind profiles, and surface observations) contribute to an improvement in the RUC forecasts. One reason the 12-h RUC did not perform as well as the 12-h Eta is probably due to the previously discussed boundary conditions differences. Also, the RUC does not employ as sophisticated a physical parameterization scheme as the Eta, due to its requirement to run rapidly.

Fig. 10 shows the performance by region of the RUC and Eta in forecasting the polar jet. The RUC performed best over the central portion of the country. This makes sense in that the central U.S. has the most wind profilers and is farthest away from the boundaries of the RUC domain. In the East, the 3-, 6-, and 9-h RUC forecasts showed significant improvement over the 12-h Eta. In the West, the RUC did not perform as well as the Eta. The RUC forecasts improved over the Central U.S. as the forecast period shortened (the 3-h and 6-h RUC scored higher than the 9-h RUC), whereas in the East and the West, there was very little difference among the 3-, 6-, and 9-h RUC.

The forecasts were also examined with regard to time of day (Fig. 11). For the forecasts valid at 0000 UTC, the 9-, 6-, and 3-h RUC performed much better than the 12-h Eta. The RUC showed no such improvement for forecasts valid at 1200 UTC. A possible explanation for the better performance at 0000 UTC is that there are about twice as many more ACARS reports available in the hours before 0000 UTC than before 1200 UTC.

A look at mid-level winds showed no improvement of the RUC over the Eta (Table 4 and Fig. 12). Two possible reasons for the better performance of the RUC at 250-mb but not at lower levels are: 1) the RUC has finer resolution at jet level due to its hybrid coordinate system; and 2) there are many more ACARS reports around 250-mb than there are at 500-mb and below.

3.2 The evaluation by HPC

Meteorologists at HPC's Monitoring and Aviation Branch (MAB) performed a similar evaluation to that by AWC. One difference was that all forecasts were compared subjectively to observations (rawinsonde and conventional aircraft reports) instead of an analysis. The observations available to NCEP's Aviation model were plotted onto a map and used as the verifying standard. The Aviation model has a 3-h data cutoff, whereas the regional models being compared here have data cutoffs of less than one and one half hours, so it is possible that data used to subjectively verify these models were not available to the models when they ran. MAB was interested in the jet-level wind forecasts and analyses. The 250-mb surface was chosen to evaluate the analyses and forecasts of the position and strength of the arctic, polar, and subtropical jets. The RUC analysis and forecasts were compared with the Eta for valid times 0000 and 1200 UTC. The verification period ran from March 18 - April 17, 1994. Listed below are the forecasts and analyses that were evaluated:

Forecasts:
12-h Eta (from 0000 and 1200 UTC runs)
12-h RUC (from 0000 and 1200 UTC runs)
9-h RUC (from 0300 and 1500 UTC runs)
6-h RUC (from 0600 and 1800 UTC runs)
3-h RUC (from 0900 and 2100 UTC runs)

Analyses:
0-h RUC (from 0000 and 1200 UTC runs)
0-h Eta (from 0000 and 1200 UTC runs)

All five forecasts valid for a particular time had to be available on the workstations in order to be counted for the evaluation. Likewise, both analyses (RUC and Eta) had to be available to be counted.

Another way in which MAB methodology differed from AWC's was that no scoring was done, only ranking. The five forecasts were compared with each other and ranked 1 (best) to 5 (worst). The analyses were also compared with each other and ranked 1 (best) and 2 (worst). In the case of ties, a middle value was chosen. A sample evaluation sheet is displayed in Fig. 13.

The results of the evaluation are listed in Table 5 and are displayed in Fig. 14. The rankings of the 3-, 6-, and 9-h RUC forecasts are reasonably comparable to the 12-h Eta and show that the RUC's updated forecasts do provide improved forecasts with shorter forecast periods. The preference (higher rank) for all three types of jets of the 12-h Eta over the 12-h RUC is to be expected since the Eta is a more sophisticated model and due to the aforementioned boundary condition differences. It also makes sense that the RUC should forecast the polar jet better than the arctic and subtropical jets. The polar jet is more likely to be in the middle of the country which is farthest from the RUC boundaries. It is also closest to wind profiler data and the largest number of ACARS reports. The arctic and subtropical jets are frequently closer to the edges of the RUC domain and are more subject to the boundary conditions and less affected by ACARS reports than the polar jet. Note also that there were only 6 cases where an arctic jet was in the domain, so the sampling may not be large enough to validate the results of the evaluation for this phenomena. The rankings of the subtropical jet show that the 12-h Eta is preferred even over the 3-h RUC. This also might be explained by the position of the subtropical jet in that its usual location is very near the southern edge of the RUC's domain, whereas the Eta's domain extends farther south. However, this result does not seem to be consistent with the scoring results for the subtropical jet from AWC (Fig. 9) for practically the same period where the RUC 3-, 6-, and 9-h forecasts received lower (better) scores. This just points out the differences between scoring and ranking, and the uncertainties associated with subjective evaluations.

3.3 The evaluation by SMG

The Spaceflight Meteorology Group evaluated the RUC on the quality of its short-range forecasts of conditions important to the take-off and landing of the Space Shuttle. Their evaluation period ran from March through mid-April 1994 and concentrated on the landing site locations of Cape Canaveral, FL, White Sands, NM, and Edwards AFB, CA. They evaluated the 3- and 6-h RUC forecasts valid at 1200 UTC only. The parameters important for shuttle operations are ceiling, visibility, low level and high level cross wind, and precipitation. The RUC fields that were used for subjectively forecasting these parameters include pressure, Montgomery stream function, wind, potential temperature, potential temperature advection, condensation pressure, relative humidity, and dewpoint. These fields were viewed on sigma, theta, and pressure surfaces displayed on workstations with capabilities developed by SMG's Techniques Development Unit.

SMG did not formally tabulate their results but they did develop impressions from their evaluation. They reported that the RUC was helpful for the diagnosis and short-term forecasting of small-scale phenomena such as short waves and moisture convergence associated with line convection. They found that it performed well in forecasting tracks of surface low pressure circulation centers. They noted a tendency to over-forecast low-level wind maxima, but found it provided good forecasts of low-level wind shifts. Finally, they found the RUC output useful in forecasting cloud coverage and ceilings from vertical motion computed from advection of pressure and condensation pressure on the isentropic surfaces.

3.4 Summary of evaluations

In any discussion of subjective scoring and ranking, it must be noted that weakness abound in judging and summarizing subjective evaluations. An instance of conflicting results has already been mentioned. The range of allowable scores is very small (1-3). The closeness in value of the average scores in Fig. 9 shows that for many of the cases, all or many of the forecasts were probably given the same score. This can be seen also in the example of a scoring sheet In Fig. 8. Also, the differences among very short-range forecasts are bound to be very small to begin with making the ranking of such forecasts quite difficult. Keeping all this in mind, from the tabulated scores and ranks, the following conclusions can be stated. During the evaluation period, in forecasting the polar and subtropical jets: a) the 3-h RUC can perform better than the 12-h Eta, b) the 6-h and 9-h RUC perform comparably to the 12-h Eta and c) the best results are with the polar jet over the central U.S. Also, the 3-h RUC performs comparably to the 12-h Eta in the forecasting of the 500-, 700-, and 850-mb wind maxima. The scores and rankings presented in this section can also give us an idea of how the RUC forecasts run from asynoptic times (not 0000 or 1200 UTC) will perform since previously at these times, there were no recently updated forecasts available.

The experiences of SMG along with the written comments from forecasters from the other two evaluation groups provide evidence that the RUC is useful in providing supplementary and updated information for short-term forecasting and diagnosing. Experience, training, and derived isentropic fields should aid in interpretation and utilization of the model output. Overall the RUC was found to be a useful and meteorologically sound system.

4. FUTURE PLANS

Many improvements are being planned and developed for the RUC by FSL. As they are successfully tested there, they will be transferred to the RUC at the NCEP. However, the RUC will continue to be committed to the requirements set down by the recommendation of the Aviation Weather Forecasting Task Force. No enhancement will be allowed to work against the RUC's strength, which is its ability to provide high quality analyses and short-range forecasts very quickly after the data become available.

Some of the improvements being considered for the RUC involve higher horizontal and vertical resolutions. A 40-km, 40-level version is being tested now and experiments are also being made with a 20-km, 50-level version. It is also envisioned that the RUC will increase in frequency, from every 3 hours to every hour. Other possible improvements include an improved analysis that allows explicit analysis of divergence, a quality control monitoring capability, the assimilation of surface temperature and moisture, and improvements to the forecasts of aviation-impact variables such as clouds, ceiling, visibility, icing, and turbulence.

5.REFERENCES

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	April 1-30, 1994			July 17-August 15, 1994		
	MAPS	RUC	MAPS-RUC	MAPS	RUC	MAPS-RUC
850	6.2	6.2	0	6.0	5.2	0.8
700	7.5	6.0	1.5	7.5	7.0	0.5
500	1.7	2.0	-0.3	7.8	5.5	2.3
400	-0.7	-0.7	0	5.0	3.3	1.7

Table 1: Comparison of the relative humidity bias in 3-hour forecasts from the MAPS system run at FSL and the RUC system run at NMC for two periods: April 1-30, 1994 and July 17-August 15, 1994.

AVIATION WEATHER CENTER
AVERAGE SCORES

(1=EXCELLENT;3=POOR)
MARCH 15 - APRIL 15, 1994

MAX WIND	VALID TIME	SECTION OF CON-TERMINOUS U.S.	# CASES	12H ETA	12H RUC	9H RUC	6H RUC	3H RUC
POLAR	00,12Z	ALL	77	1.51	1.64	1.45	1.43	1.42
POLAR	00,12Z	WEST	29	1.38	1.69	1.55	1.55	1.48
POLAR	00,12Z	CENTRAL	22	1.46	1.36	1.32	1.18	1.18
POLAR	00,12Z	EAST	26	1.69	1.81	1.46	1.50	1.54
POLAR	00Z	ALL	32	1.62	1.75	1.44	1.44	1.31
POLAR	12Z	ALL	45	1.42	1.56	1.47	1.42	1.49
SUBTROPICAL	00,12Z	ALL	75	1.59	1.69	1.57	1.49	1.48
SUBTROPICAL	00,12Z	WEST	27	1.48	1.78	1.48	1.52	1.52
SUBTROPICAL	00,12Z	CENTRAL	21	1.52	1.57	1.48	1.33	1.29
SUBTROPICAL	00,12Z	EAST	27	1.74	1.70	1.74	1.59	1.59
SUBTROPICAL	00Z	ALL	31	1.52	1.71	1.55	1.48	1.52
SUBTROPICAL	12Z	ALL	44	1.64	1.68	1.59	1.50	1.45
500 MB WIND	00,12Z	WEST	29	1.45	1.55	1.59	1.52	1.41
700 MB WIND	00,12Z	CENTRAL	22	1.55	1.45	1.45	1.55	1.59
850 MB WIND	00,12Z	EAST	30	1.90	1.90	1.90	1.93	2.00

Table 2.

AVIATION WEATHER CENTER
AVERAGE RANKS

(1=BEST; 5=WORST)
MARCH 15 - APRIL 15, 1994

MAX WIND	VALID TIME	SECTION OF CON-TERMINOUS U.S.	# CASES	12H ETA	12H RUC	9H RUC	6H RUC	3H RUC
POLAR	00,12Z	ALL	77	2.9	3.9	3.2	2.8	2.4
POLAR	00,12Z	WEST	29	2.5	4.1	3.2	2.9	2.3
POLAR	00,12Z	CENTRAL	22	3.2	4.0	3.3	2.5	2.2
POLAR	00,12Z	EAST	26	3.0	3.5	2.9	2.9	2.7
POLAR	00Z	ALL	32	3.1	4.0	3.1	2.8	2.2
POLAR	12Z	ALL	45	2.7	3.8	3.2	2.8	2.6
SUBTROPICAL	00,12Z	ALL	75	2.7	3.8	3.3	2.8	2.4
SUBTROPICAL	00,12Z	WEST	27	2.3	4.0	3.4	3.0	2.3
SUBTROPICAL	00,12Z	CENTRAL	21	3.1	4.4	3.2	2.4	1.8
SUBTROPICAL	00,12Z	EAST	27	2.8	3.2	3.3	2.9	2.9
SUBTROPICAL	00Z	ALL	31	2.4	4.2	3.5	2.8	2.3
SUBTROPICAL	12Z	ALL	44	2.9	3.5	3.2	2.9	2.5
500 MB WIND	00,12Z	WEST	29	2.6	3.6	3.2	3.2	2.4
700 MB WIND	00,12Z	CENTRAL	22	3.3	3.0	2.7	2.9	3.2
850 MB WIND	00,12Z	EAST	30	2.6	3.1	3.3	3.2	3.0

Table 3.

AVIATION WEATHER CENTER

MARCH 15 - APRIL 15, 1994
VALID TIMES 00Z, 12Z

AVERAGE SCORES

(1=EXCELLENT; 3=POOR)

PARAMETER	SECTION OF CON-TERMINOUS U.S.	# CASES	12H ETA	12H RUC	9H RUC	6H RUC	3H RUC
500 MB TEMP	WEST	28	1.54	1.75	1.64	1.61	1.61
700 MB TEMP	CENTRAL	22	1.32	1.50	1.55	1.45	1.41
850 MB TEMP	EAST	29	1.45	1.79	1.66	1.72	1.83
500MB DP DPR	WEST	28	1.75	2.21	2.14	2.11	2.11
700MB DP DPR	CENTRAL	22	1.55	2.32	2.32	2.36	2.32
850MB DP DPR	EAST	29	2.10	2.38	2.41	2.45	2.41

AVERAGE RANKINGS

(1=BEST, 5=WORST)

PARAMETER	SECTION OF CON-TERMINOUS U.S.	# CASES	12H ETA	12H RUC	9H RUC	6H RUC	3H RUC
500 MB TEMP	WEST	28	2.6	3.6	3.4	3.0	2.3
700 MB TEMP	CENTRAL	22	2.1	3.3	3.4	3.2	2.8
850 MB TEMP	EAST	29	2.5	3.5	2.9	2.9	3.1
500MB DP DPR	WEST	28	2.0	3.7	3.3	3.2	2.9
700MB DP DPR	CENTRAL	22	1.6	3.6	3.4	3.6	3.0
850MB DP DPR	EAST	29	2.3	2.9	3.2	3.4	3.3

Table 4.

MONITORING & AVIATION BRANCH
MARCH 18 - APRIL 17, 1994

AVERAGE RANK OF FORECASTS

(1=BEST, 5=WORST)
VALID AT 00Z AND 12Z

	# CASES	12H ETA	12H RUC	9H RUC	6H RUC	3H RUC
ARCTIC JET	6	2.5	3.5	3.2	3.3	2.5
POLAR JET	30	2.9	3.7	2.9	3	2.3
SUBTROPICAL JET	22	2.2	4	3.1	3.1	2.7

RATINGS OF ANALYSES

(00Z AND 12Z)

RUC VS ETA

	# CASES	RUC WIN/TIE/LOSS	% WINS	% WIN OR TIE	% LOSS
ARCTIC JET	8	0 - 5 - 3	0	62	38
POLAR JET	32	11 - 9 - 12	34	72	38
SUBTROPICAL JET	25	6 -10 - 9	24	64	36

Table 5.

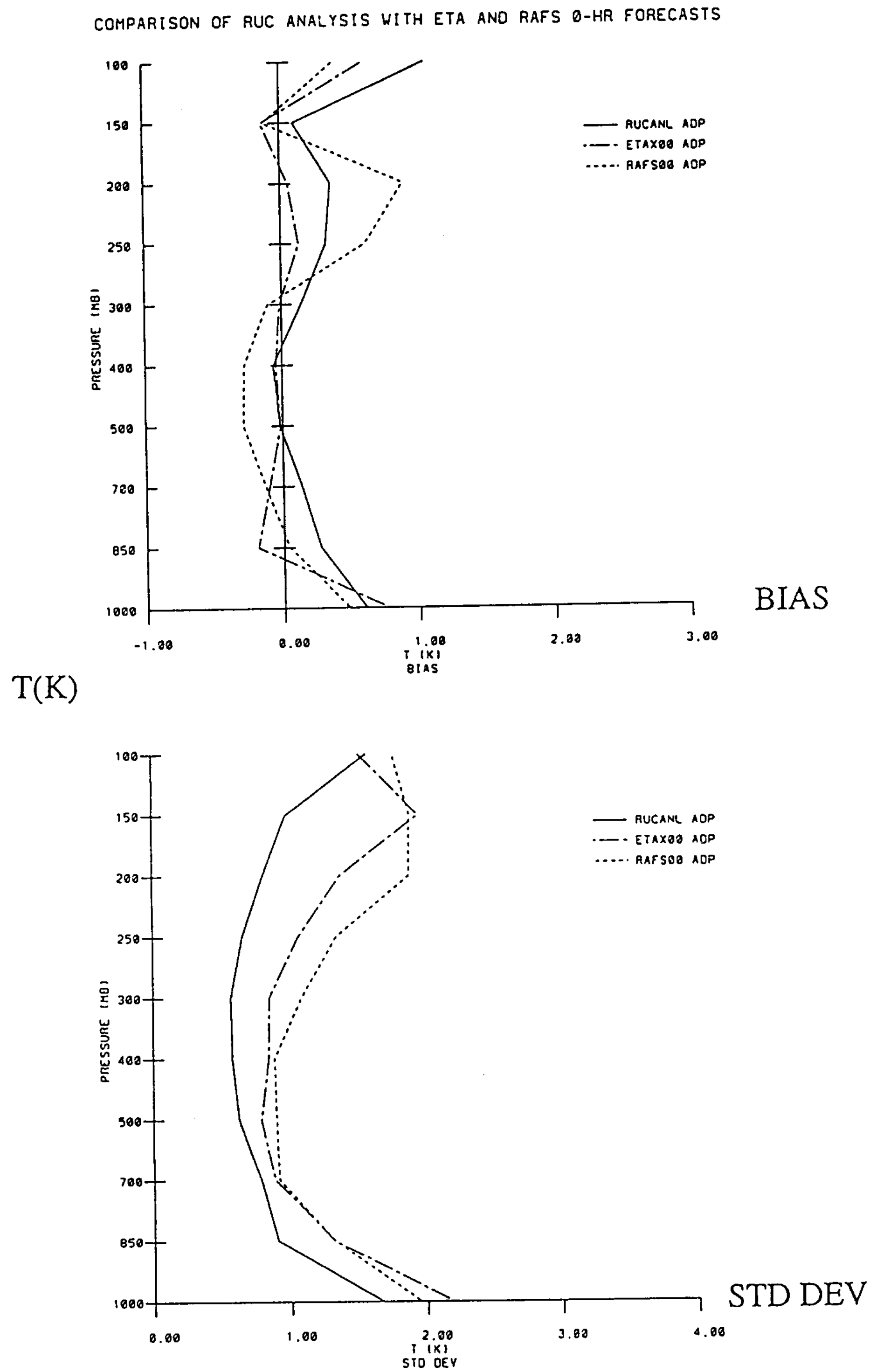


Figure 1. Bias and standard deviation of the differences between rawinsonde temperatures and a) the analysis, b) the 3-h forecast and c) the 12-h forecast from the RUC, the early Eta and the RAFS.

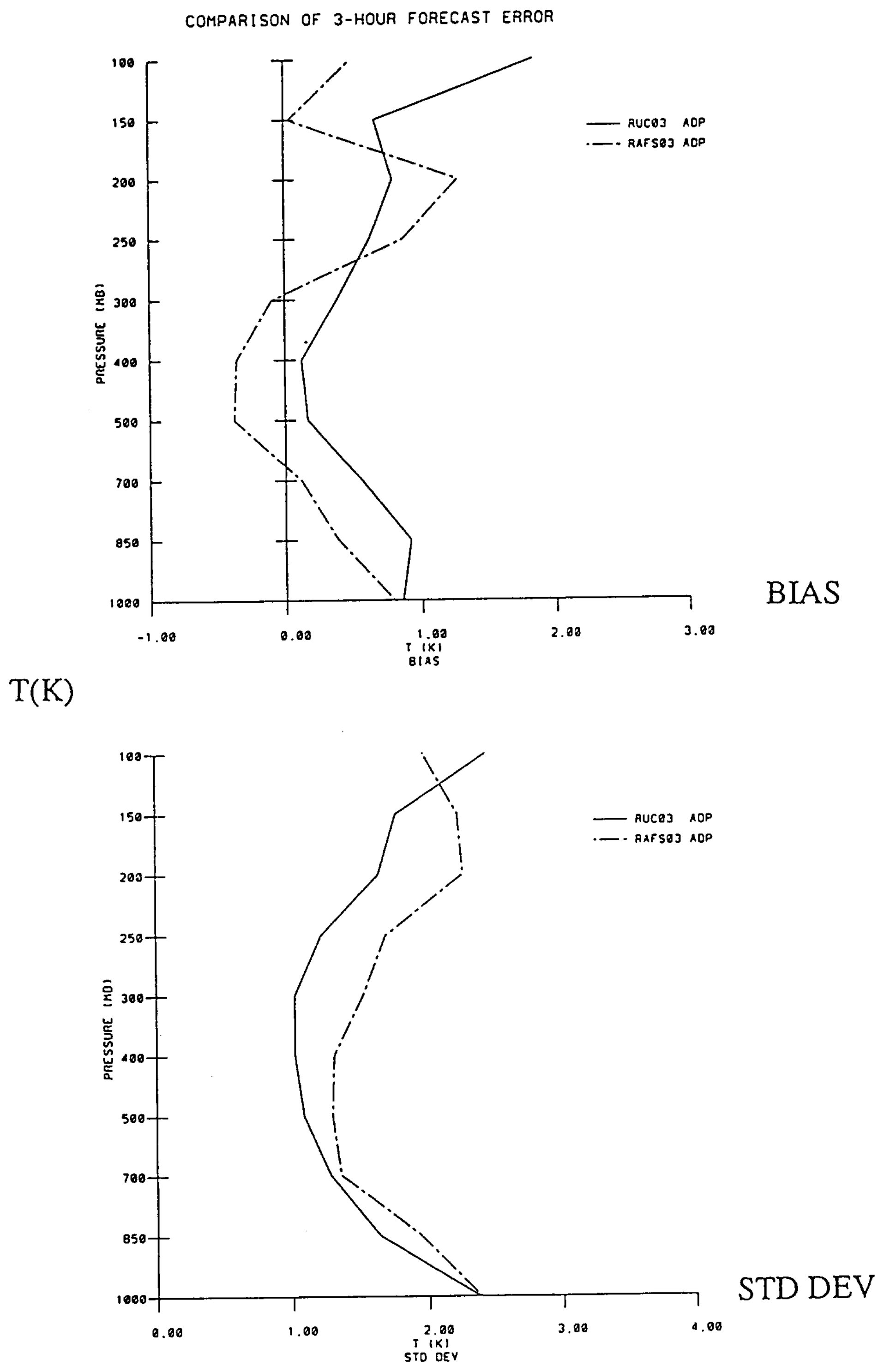

COMPARISON OF 3-HOUR FORECAST ERROR
PRESSURE (MB)
100
150
200
250
300
400
500
700
850
1000
RUC03 ADP
RAFS03 ADP
-1.00
0.00
1.00
2.00
3.00
T (K)
BIAS
BIAS
T(K)
PRESSURE (MB)
100
150
200
250
300
400
500
700
850
1000
RUC03 ADP
RAFS03 ADP
0.00
1.00
2.00
3.00
4.00
T (K)
STD DEV
STD DEV

Figure 1b

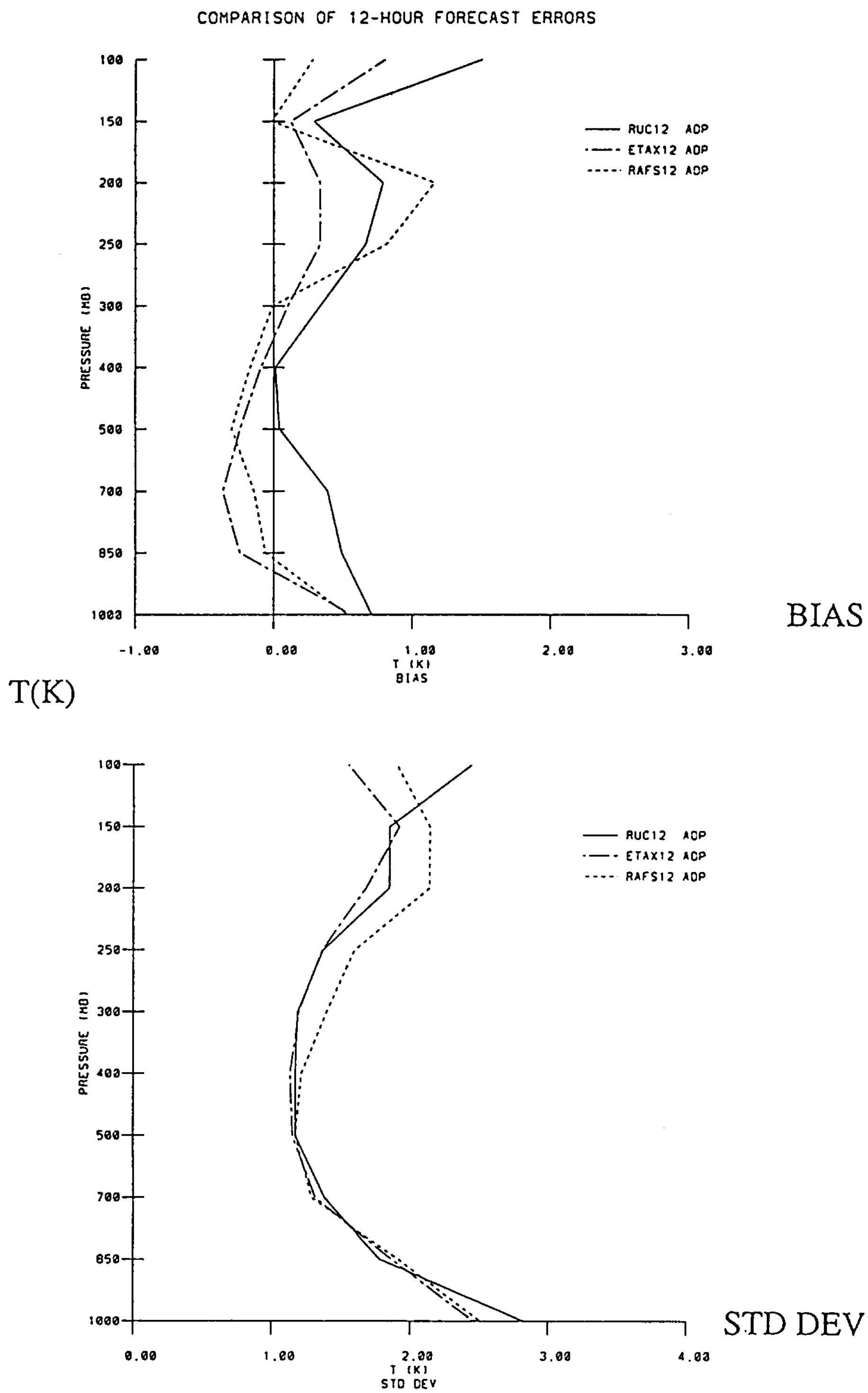

COMPARISON OF 12-HOUR FORECAST ERRORS
PRESSURE (MB)
100
150
200
250
300
400
500
700
850
1000
RUC12 ADP
ETAX12 ADP
RAFS12 ADP
-1.00
0.00
1.00
2.00
3.00
T (K)
BIAS
BIAS
T(K)
PRESSURE (MB)
100
150
200
250
300
400
500
700
850
1000
RUC12 ADP
ETAX12 ADP
RAFS12 ADP
0.00
1.00
2.00
3.00
4.00
T (K)
STD DEV
STD DEV

Figure 1c

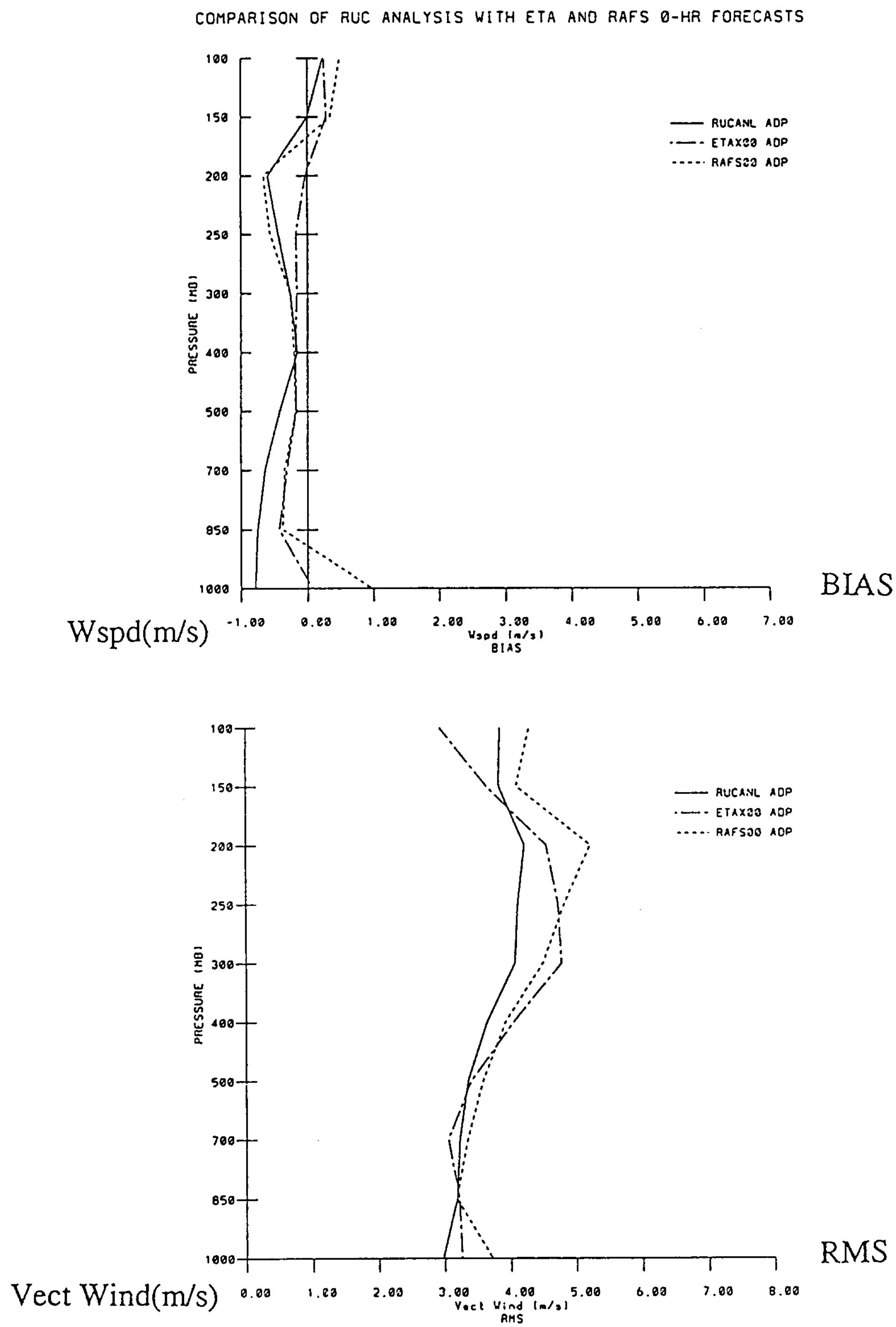
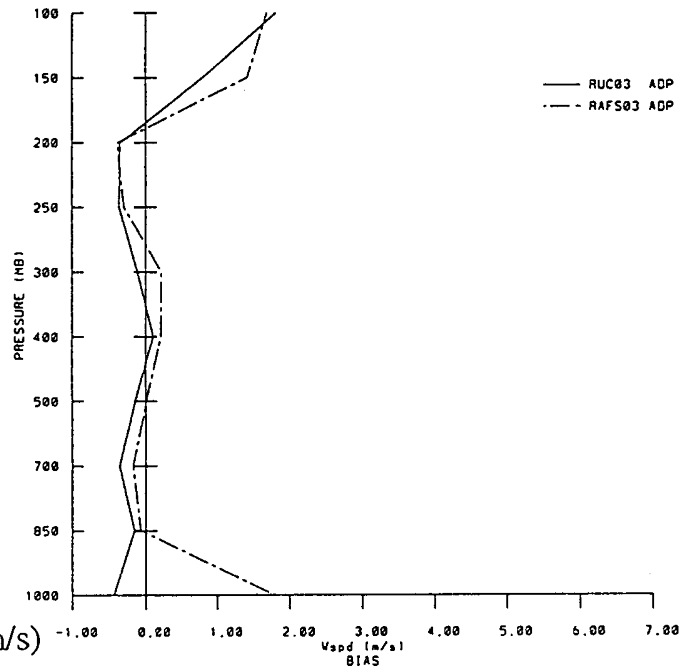


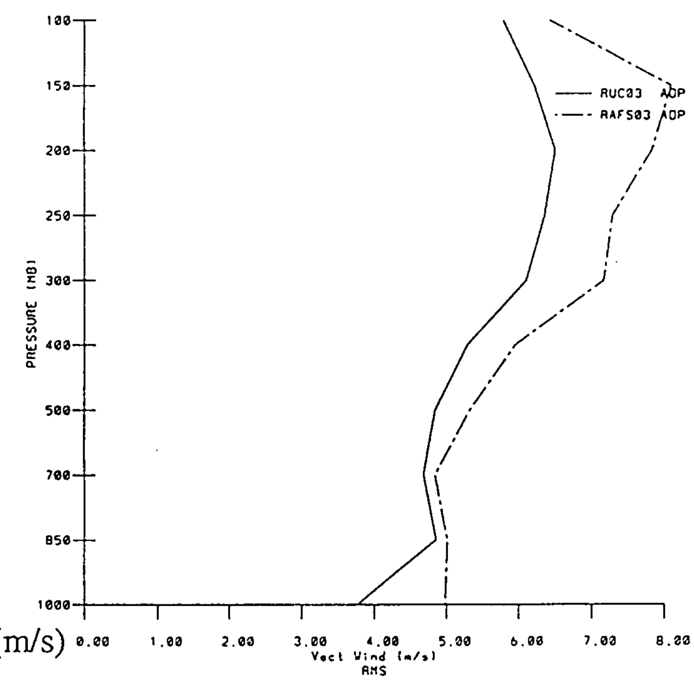
Figure 2. Wind speed bias and the root-mean-square vector wind error computed from rawinsonde winds and a) the analysis, b) the 3-h forecast and c) the 12-h forecast from the RUC, the early Eta and the RAFS.

COMPARISON OF 3-HOUR FORECAST ERROR



BIAS

Wspd(m/s)



RMS

Vect Wind(m/s)

Figure 2b

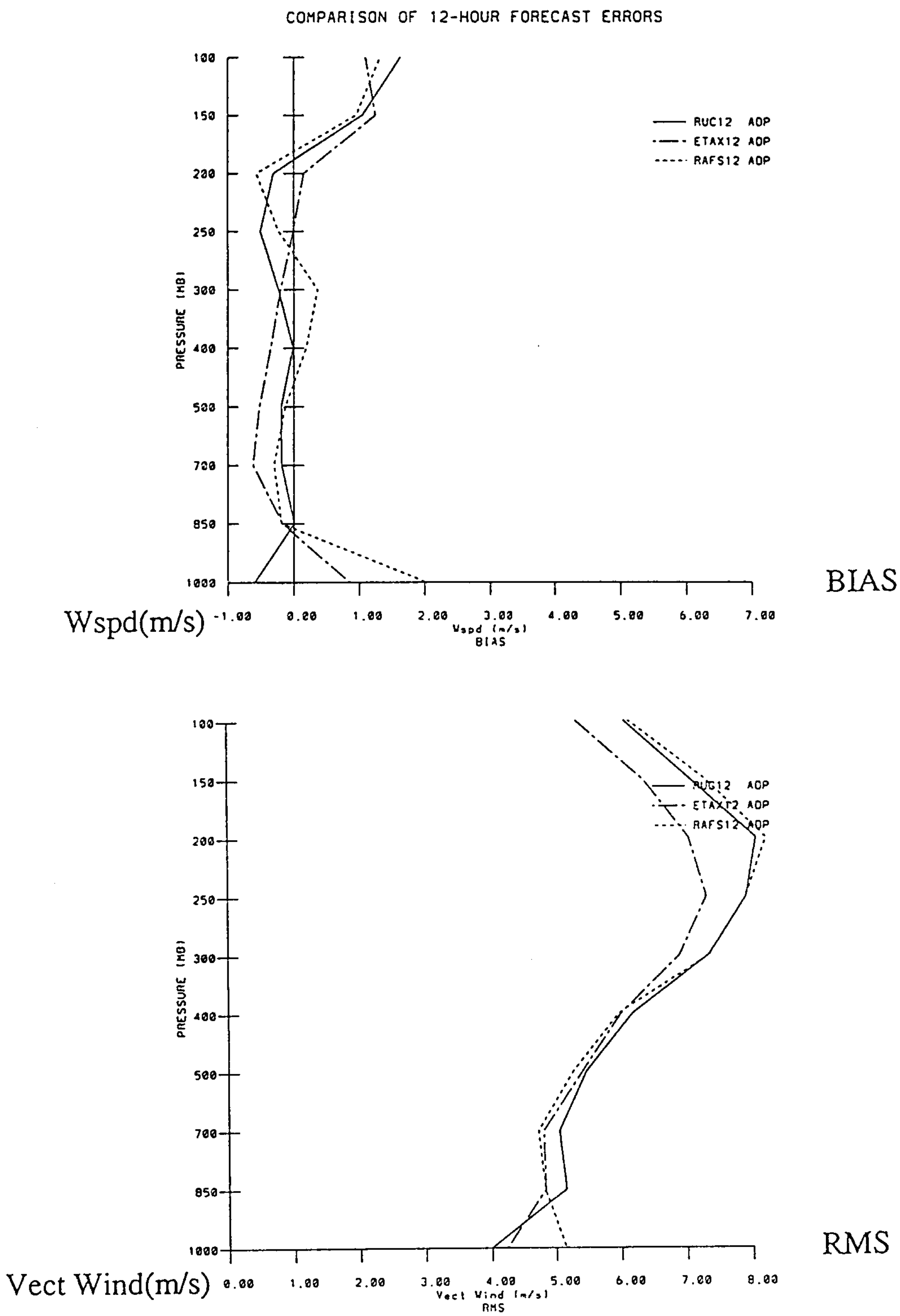

COMPARISON OF 12-HOUR FORECAST ERRORS
RUC12 ADP
ETAX12 ADP
RAFS12 ADP
PRESSURE (MB)
Wspd (m/s)
BIAS
BIAS
Wspd(m/s)
Vect Wind (m/s)
RMS
RMS
Vect Wind(m/s)

Figure 2c

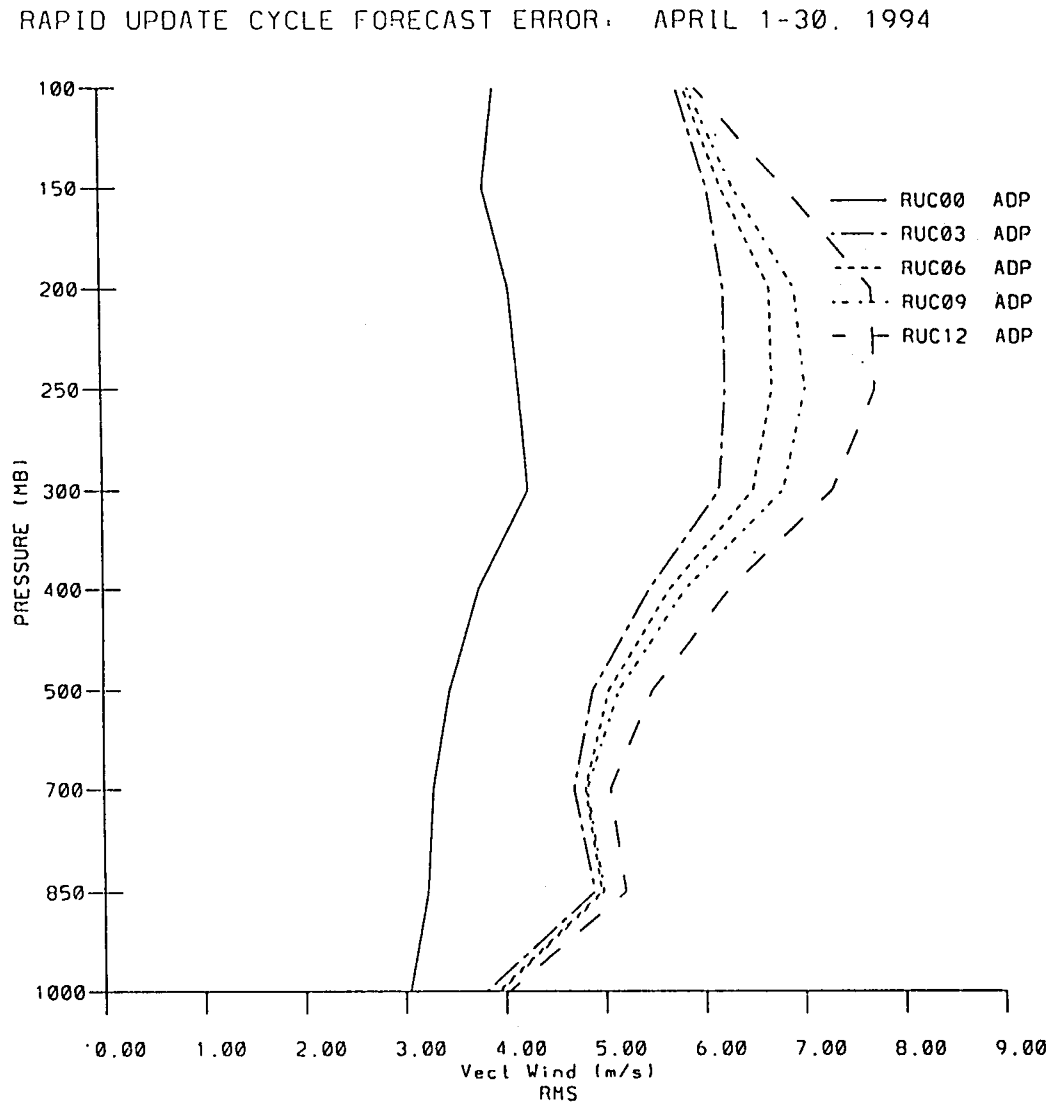
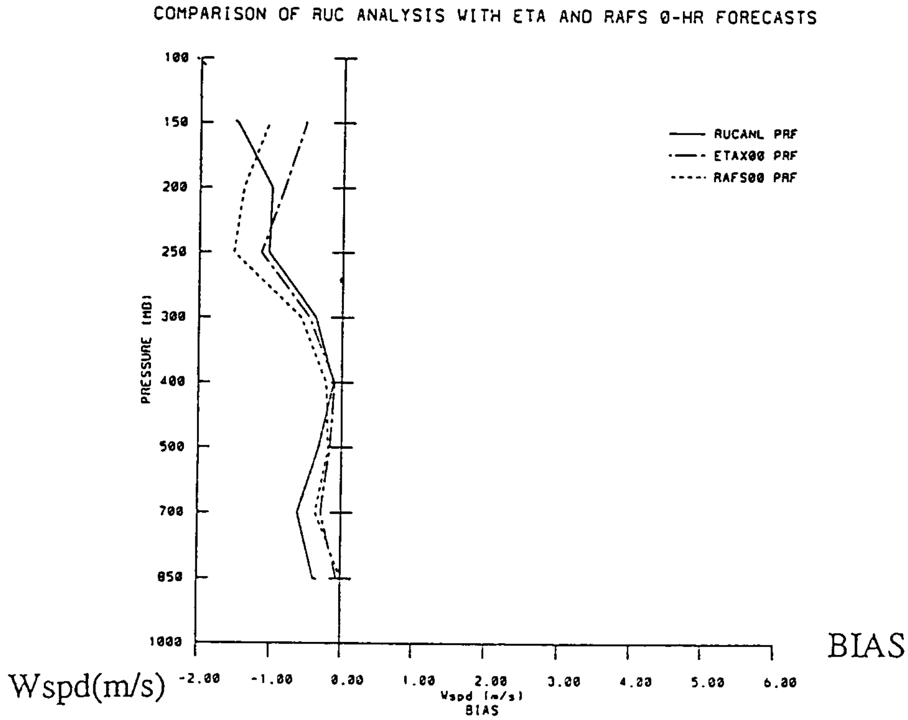


Figure 3. Comparison of root-mean-square vector wind error computed from rawinsonde winds for the RUC analysis and 3-, 6-, 9-, and 12-h forecast.



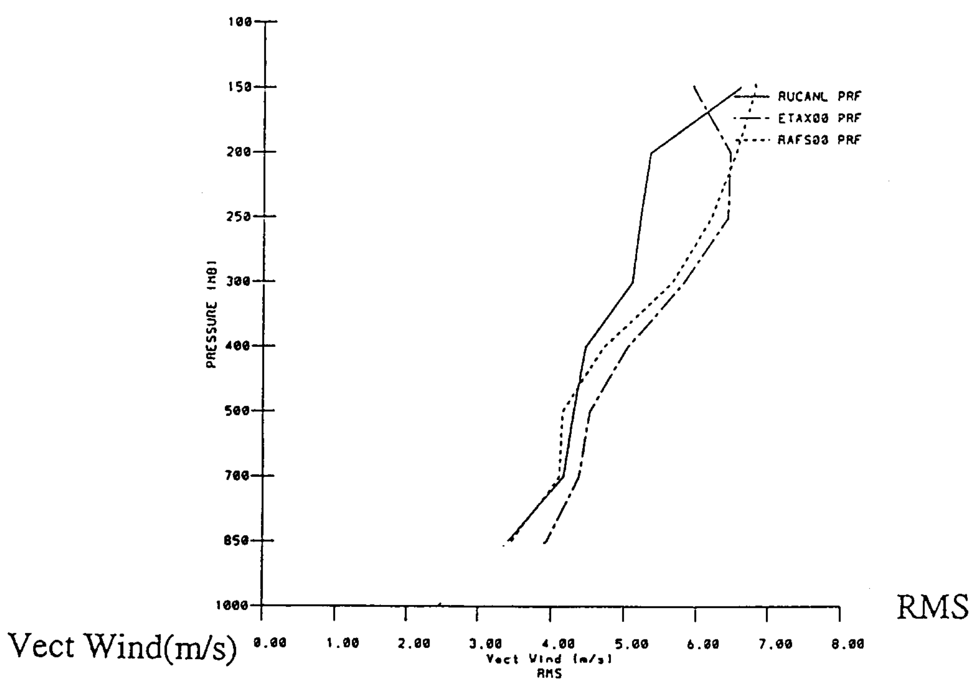


Figure 4. Wind speed bias and the root-mean-square vector wind 6-h forecast error computed from profiler and automated aircraft winds and a) the analysis, b) the 3-h forecast and c) the 12-h forecast from the RUC, the early Eta, and the RAFS.

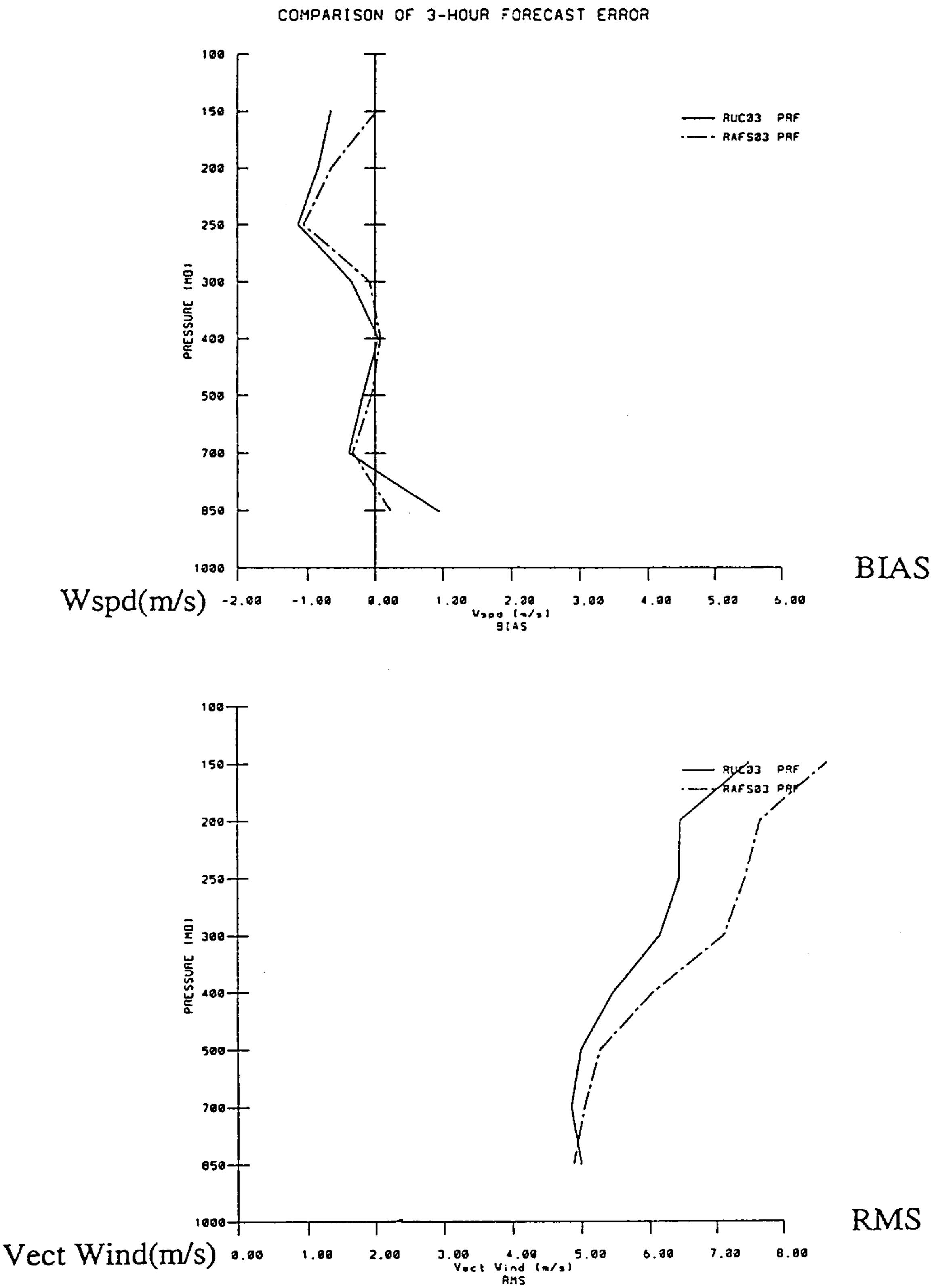

COMPARISON OF 3-HOUR FORECAST ERROR
RUC03 PRF
RAFS03 PRF
PRESSURE (MB)
100
150
200
250
300
400
500
700
850
1000
BIAS
Wspd(m/s)
-2.00
-1.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Wspd (m/s)
BIAS
RUC03 PRF
RAFS03 PRF
PRESSURE (MB)
RMS
Vect Wind(m/s)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
Vect Wind (m/s)
RMS

Figure 4b

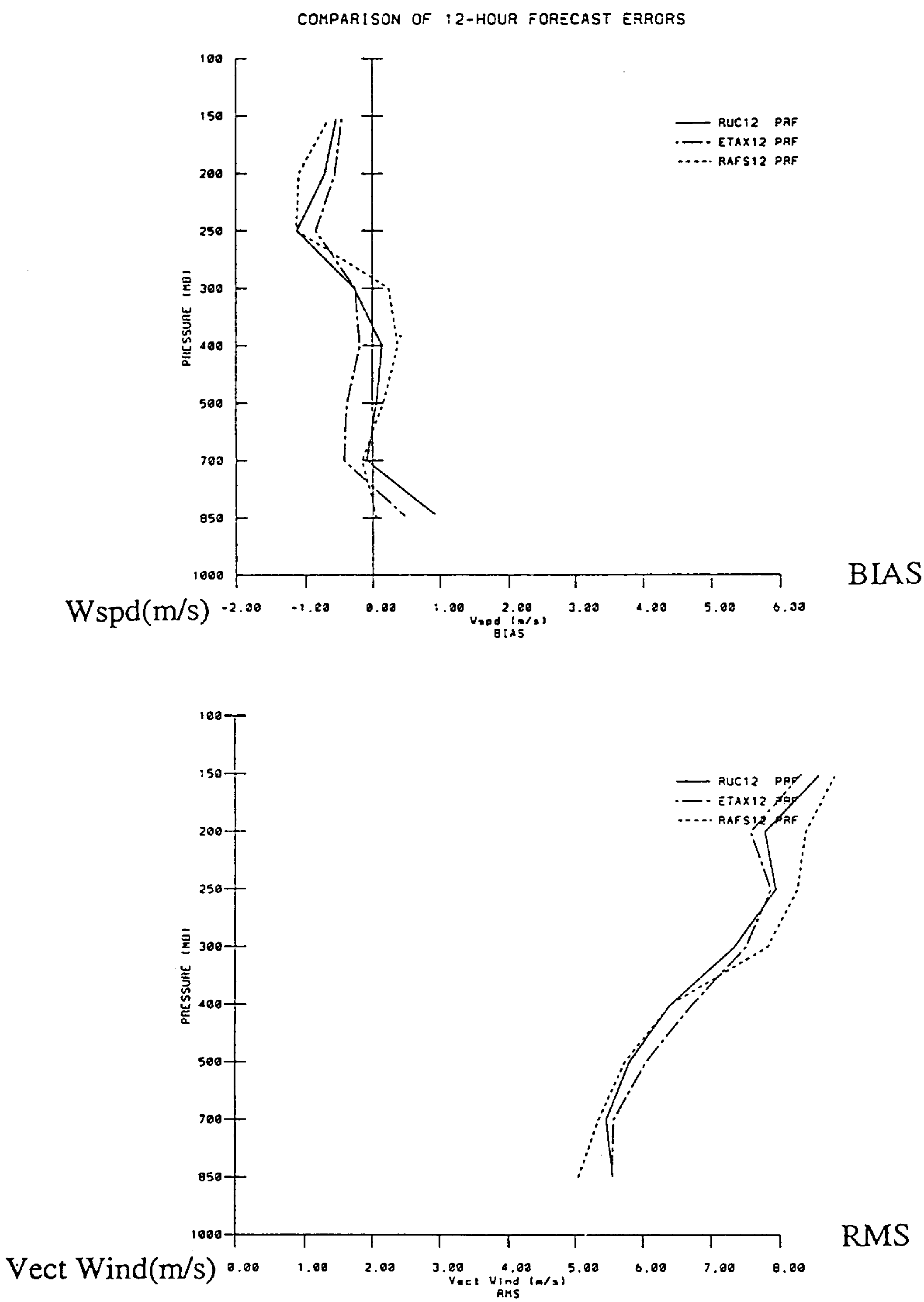
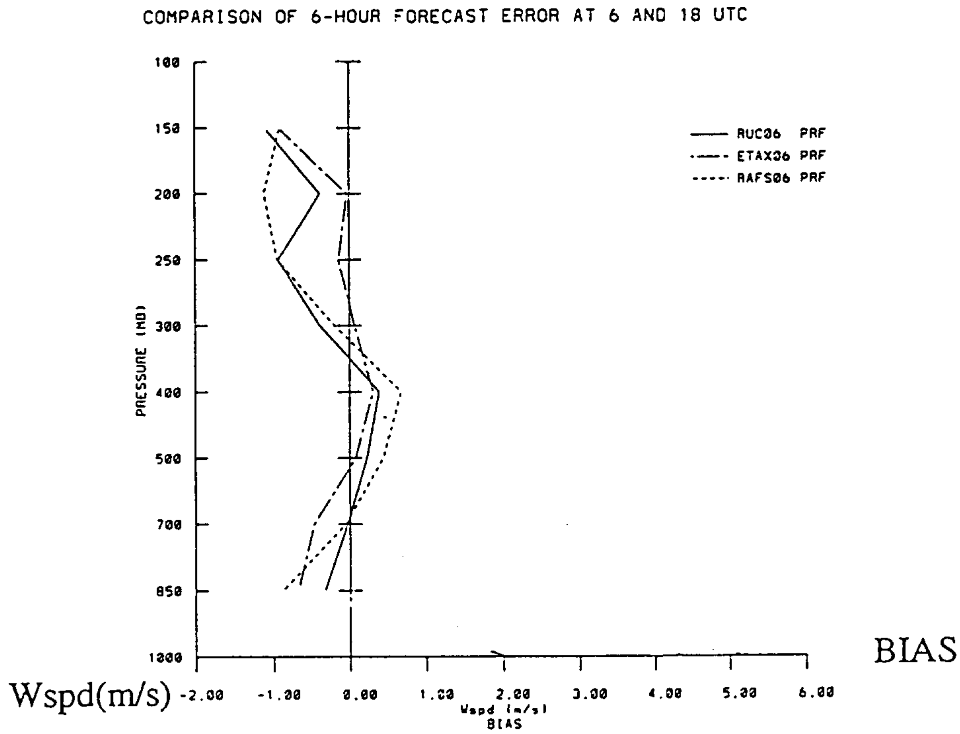

COMPARISON OF 12-HOUR FORECAST ERRORS
RUC12 PRF
ETAX12 PRF
RAFS12 PRF
PRESSURE (MB)
BIAS
Wspd(m/s)
Vspd (m/s)
BIAS
RUC12 PRF
ETAX12 PRF
RAFS12 PRF
PRESSURE (MB)
RMS
Vect Wind(m/s)
Vect Wind (m/s)
RMS

Figure 4c



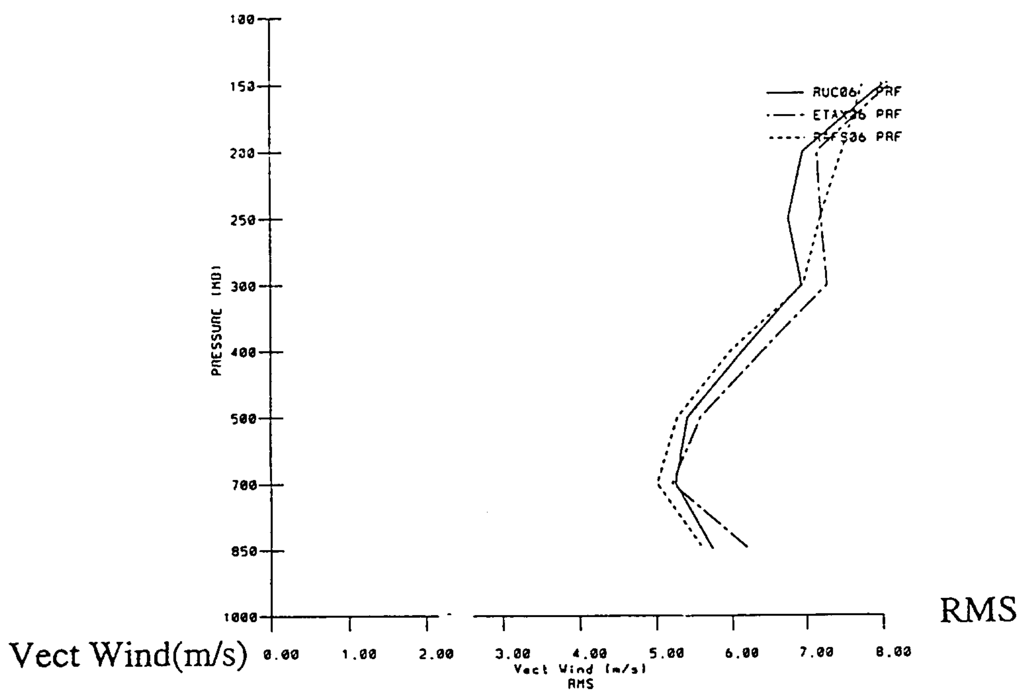


Figure 5. Wind speed bias and the root-mean-square vector wind error computed from profiler and automated aircraft winds for the RUC, the early Eta, and the RAFS verified at 0600 and 1800 UTC.

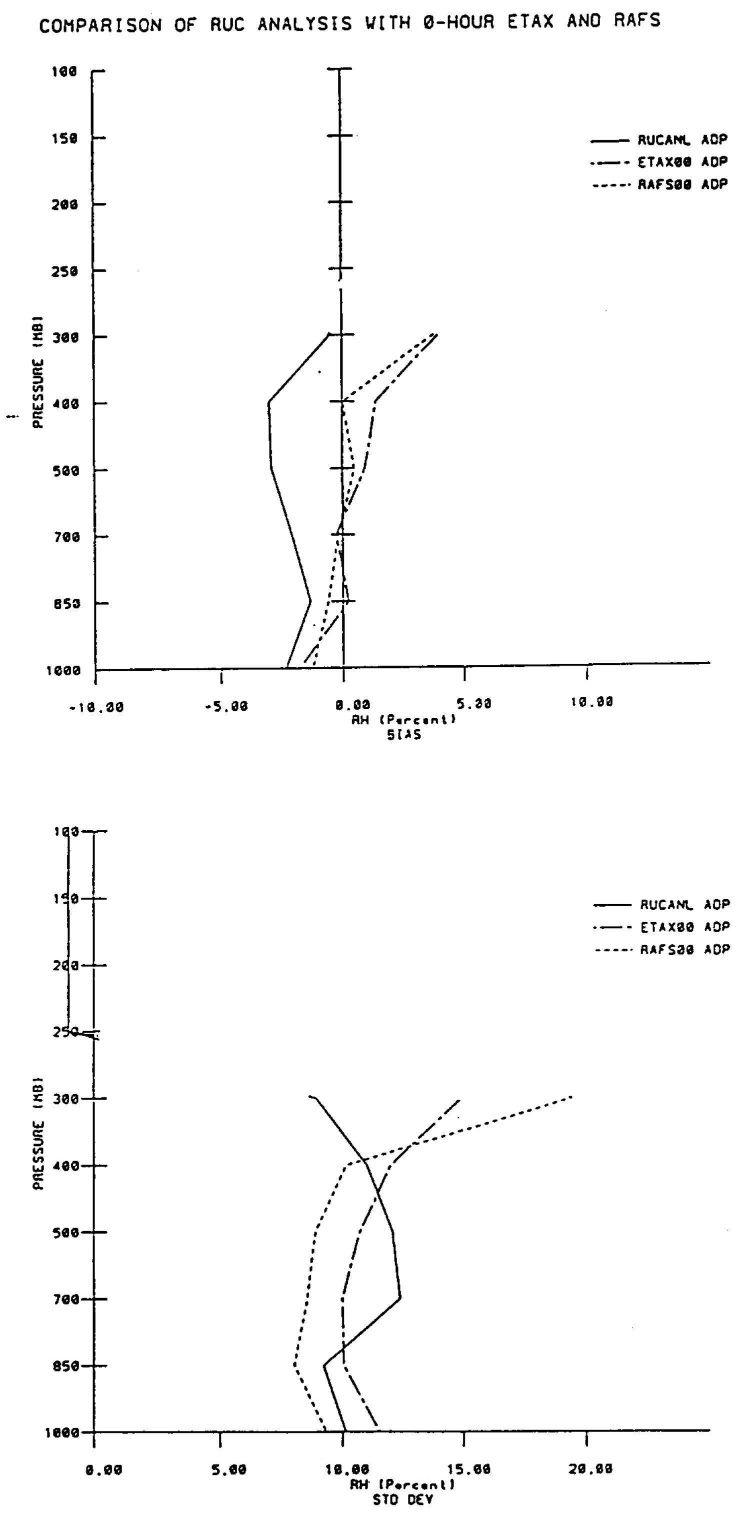


Figure 6. Bias and standard deviation of the differences between relative humidity computed from rawinsonde observations and a) the analysis, b) the 3-h forecast, and c) the 12-h forecast from the RU(the early Eta, and the RAFS.

COMPARISON OF 3-HOUR FORECASTS

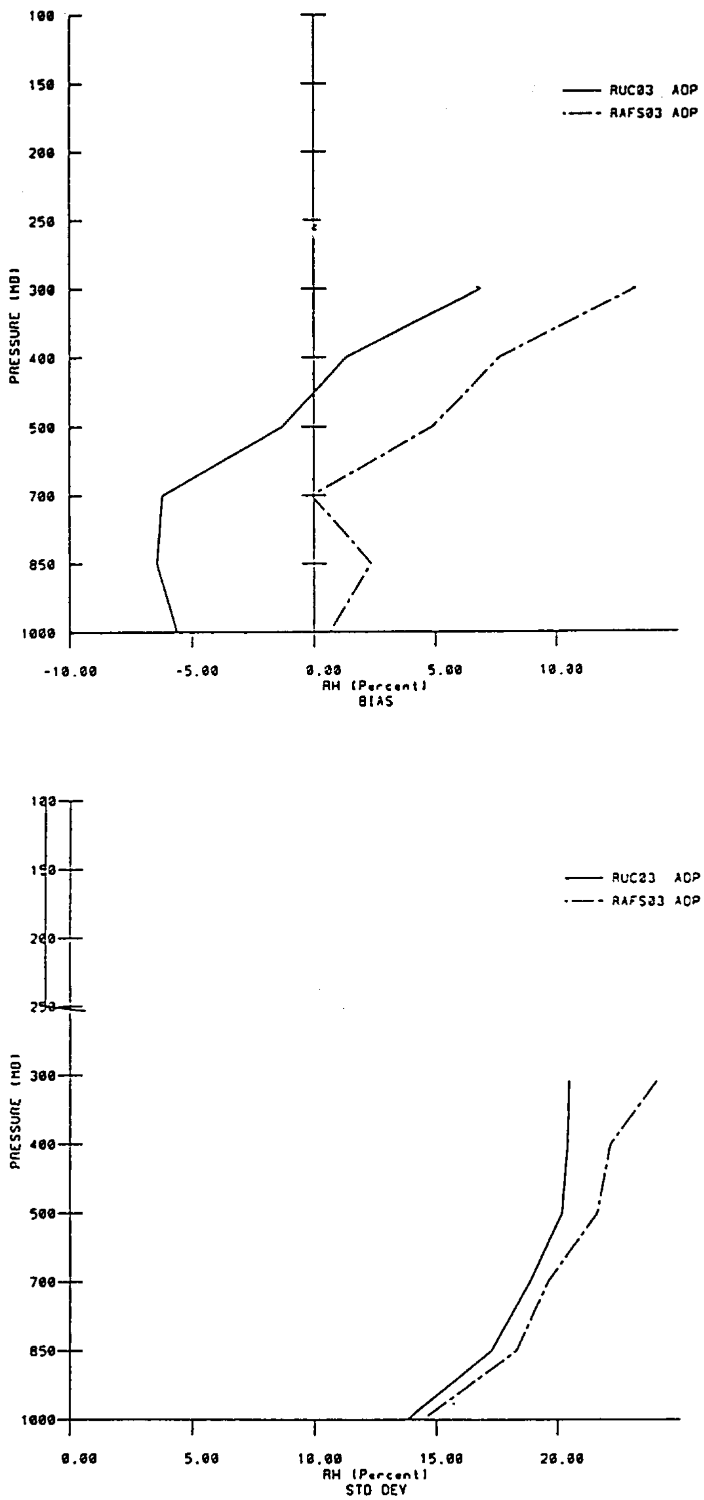


Figure 6b

COMPARISON OF 12-HOUR FORECAST ERROR

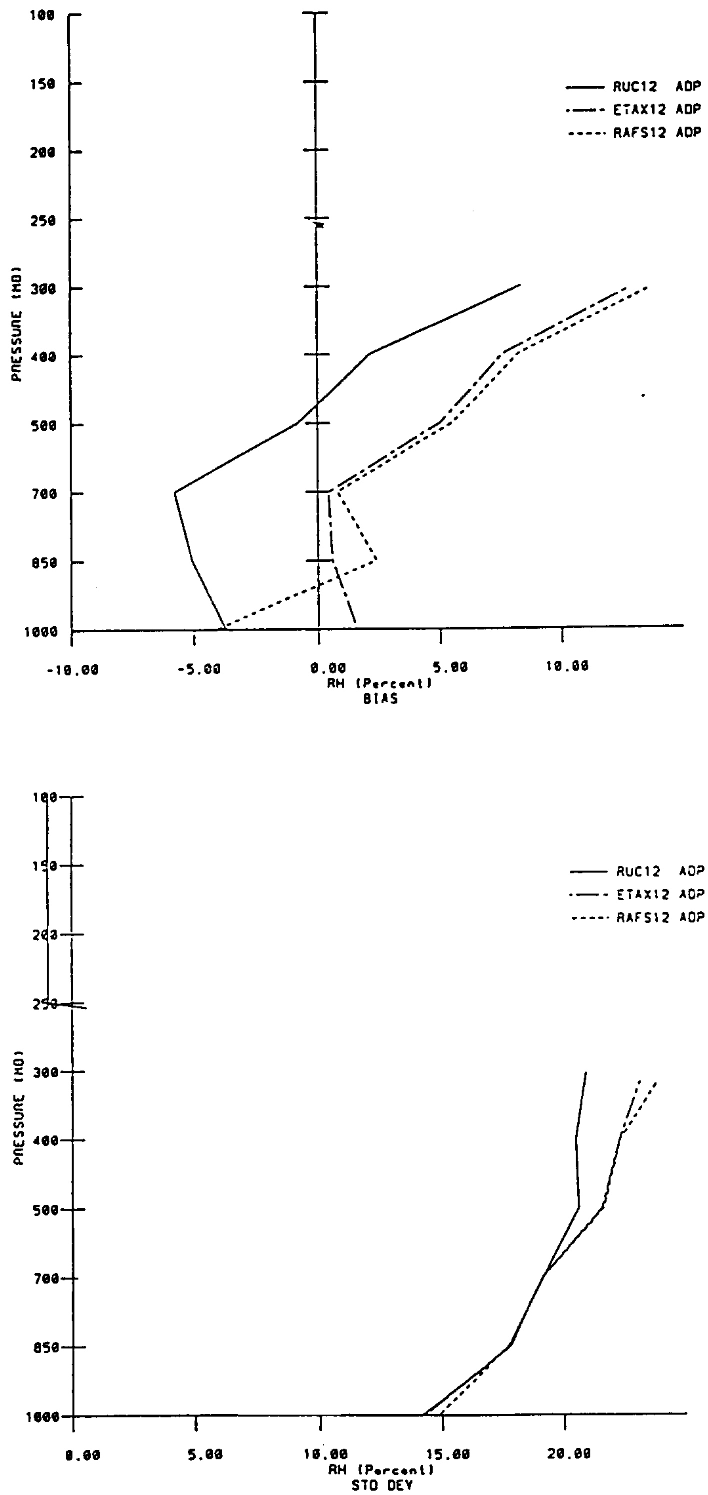


Figure 6c

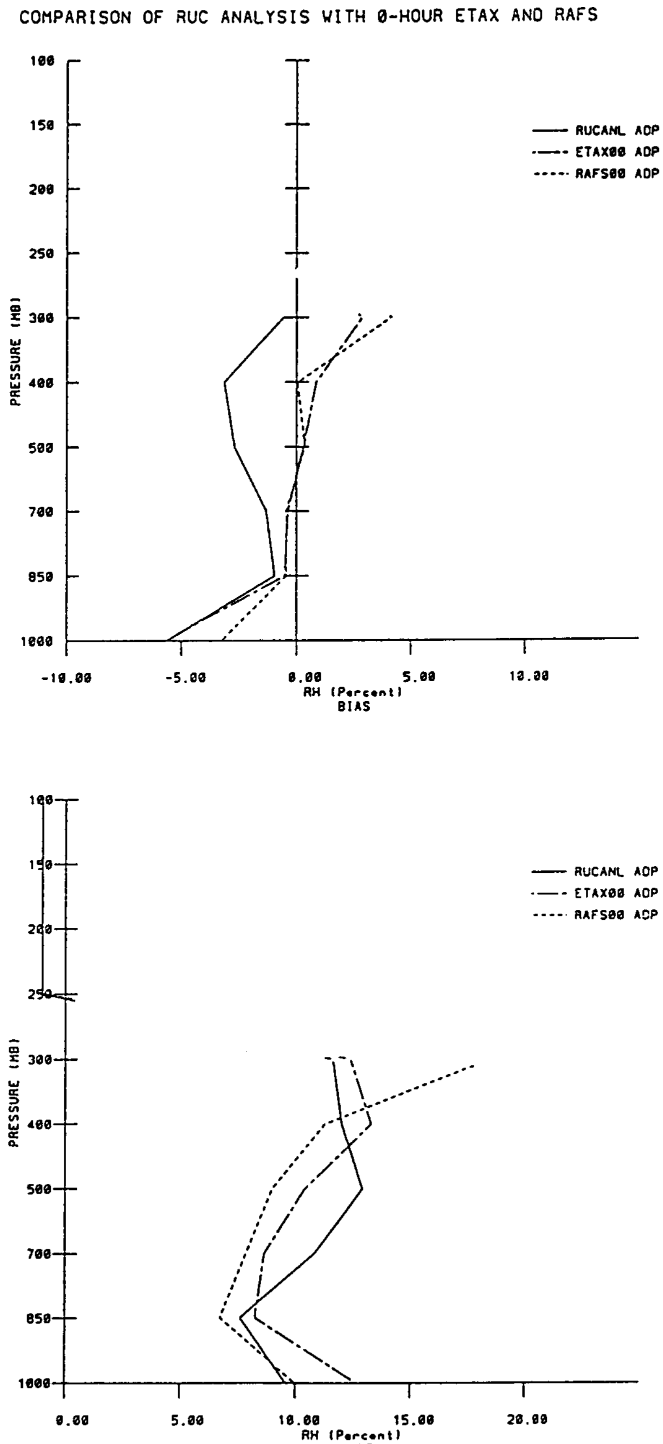


Figure 7. Same as Figure 6, except for the period July 17 - August 15, 1994 with corrected error involving moisture variable transformations.

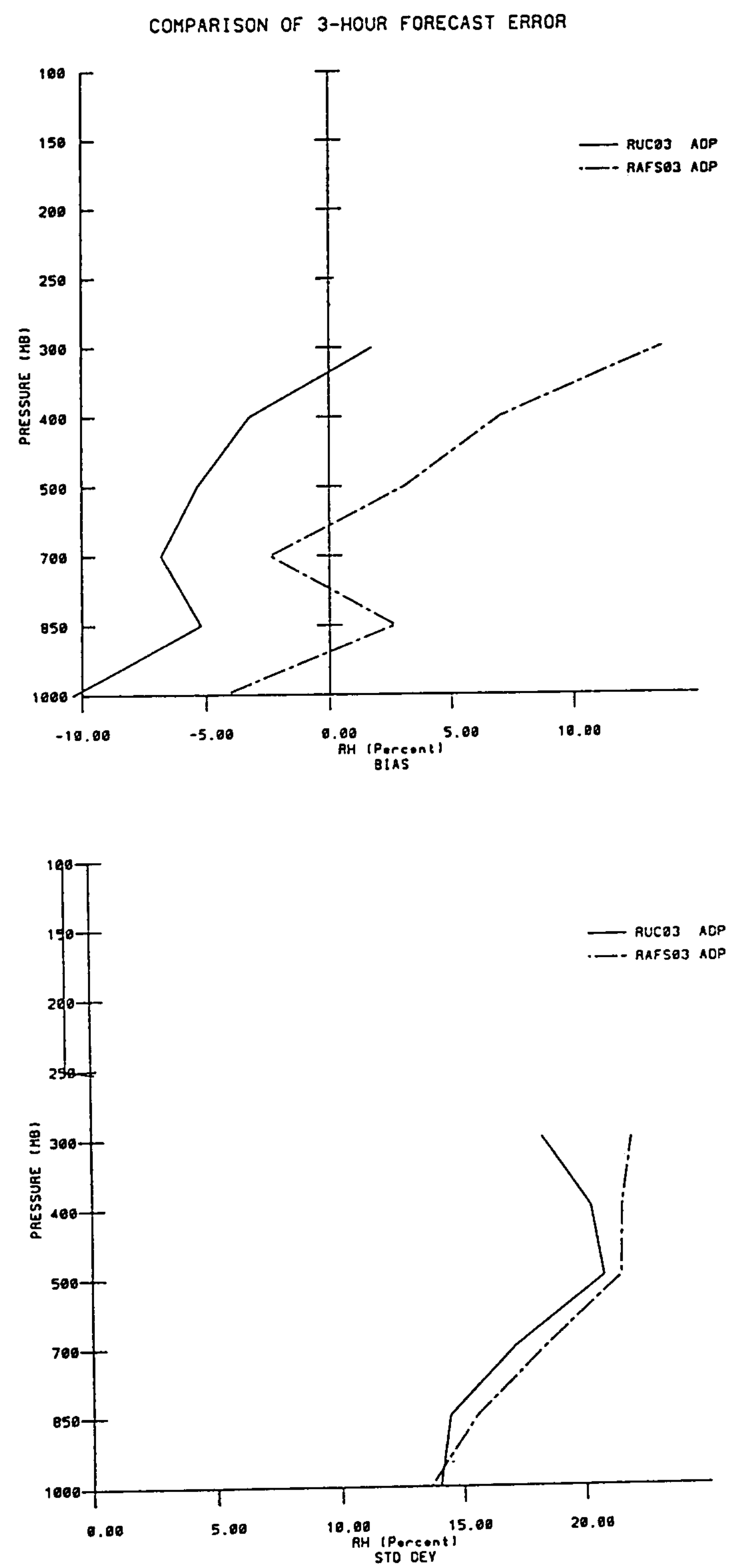
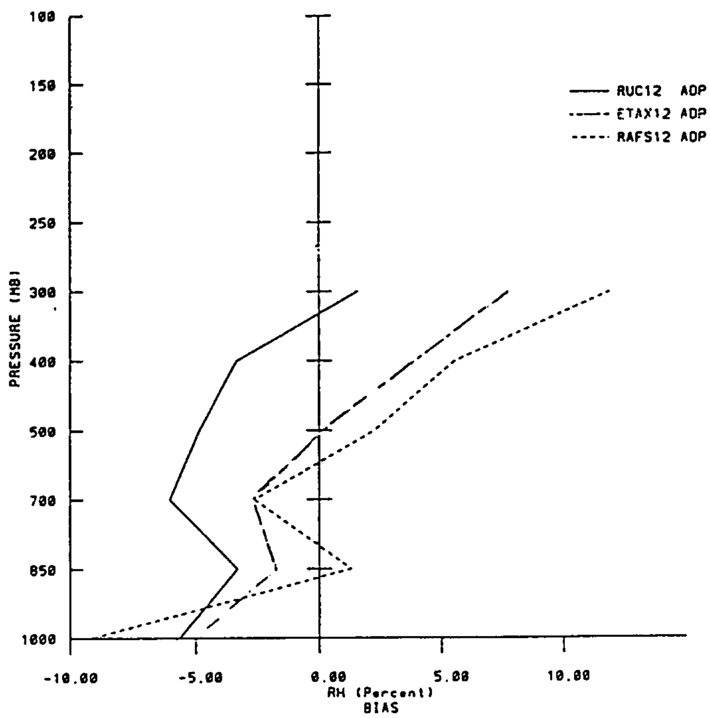

COMPARISON OF 3-HOUR FORECAST ERROR
RUC03 ADP
RAFS03 ADP
PRESSURE (MB)
100
150
200
250
300
400
500
700
850
1000
-10.00
-5.00
0.00
5.00
10.00
RH (Percent)
BIAS
RUC03 ADP
RAFS03 ADP
PRESSURE (MB)
100
150
200
250
300
400
500
700
850
1000
0.00
5.00
10.00
15.00
20.00
RH (Percent)
STD DEV

Figure 7b

COMPARISON OF 12-HOUR FORECAST ERROR



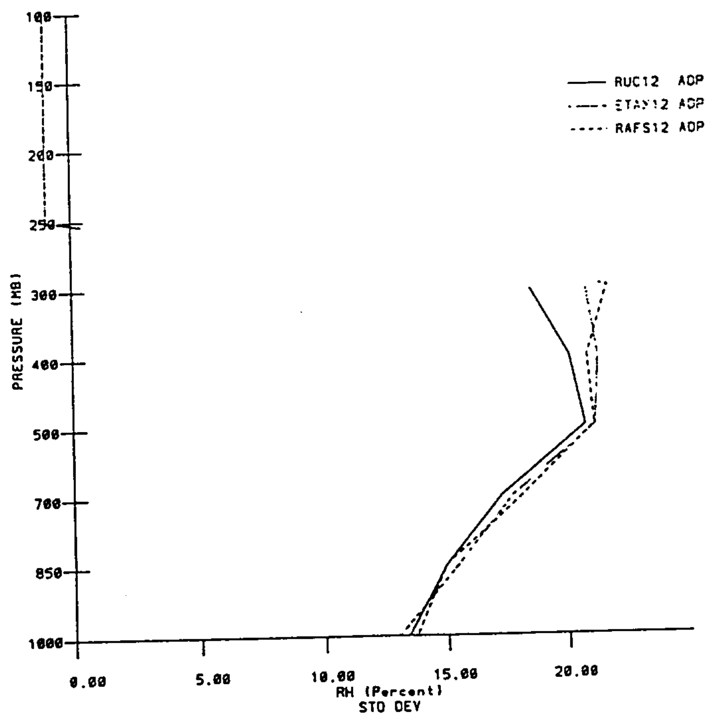


Figure 7c

RAPID UPDATE CYCLE SUBJECTIVE EVALUATION FORM
RUC verses ETA
National Aviation Weather Advisory Unit

EVALUATOR: __________ ______________ FA DESK: C

VALID DAY: 3/19 VALID TIME: 00 Z

1. **Score** the accuracy of each forecast field as it compares to the analysis on a scale of 1 to 3. A "1" would be excellent, "2" fair, and "3" poor.

2. **Rank** the forecast fields by comparing them to each other. The forecast closest to the analysis would receive a "1". The forecast deviating the most would receive a 5.

		FORECASTS									
EVALUATED PARAMETER	FA DESK	12H ETA		12H RUC		09H RUC		06H RUC		03H RUC	
		SCR	RNK	SCR	RNK	SCR	RNK	SCR	RNK	SCR	RNK
250mb Polar Jet Speed/Position	ALL	2	4	2	5	2	3	1	2	1	1
250mb Sbtrp.Jet Speed/Position	ALL	2	4	2	5	2	3	1	2	1	1
500mb Max Wind Speed/Position	WEST										
700mb Max Wind Speed/Position	CNTR	2	5	1	4	1	1	1	2	1	3
850mb Max Wind Speed/Position	EAST										
500mb Temperature (0 to -20 C)	WEST										
700mb Temperature (0 to -20 C)	CNTR	1	2	1	5	1	4	1	3	1	1
850mb Temperature (0 to -20 C)	EAST										
500mb Dwpt Depression (<= 5 C)	WEST										
700mb Dwpt Depression (<= 5 C)	CNTR	1	1	2	3	2	5	2	4	2	2
850mb Dwpt Depression (<= 5 C)	EAST										

What is the general 500mb flow regime over the contiguous U.S. using the following abbreviations? TRT

1. Ridge west, trof east (RT). 2. Trof west, ridge east (TR). 3. Trof west, ridge cntrl, trof east (TRT). 4. Ridge west, trof cntrl, ridge east (RTR). 5. Zonal.

Note any comments such as model biases, strengths or weaknesses on the back of this sheet.

Figure 8. Example of the form used by AWC forecasters to evaluate the RUC.

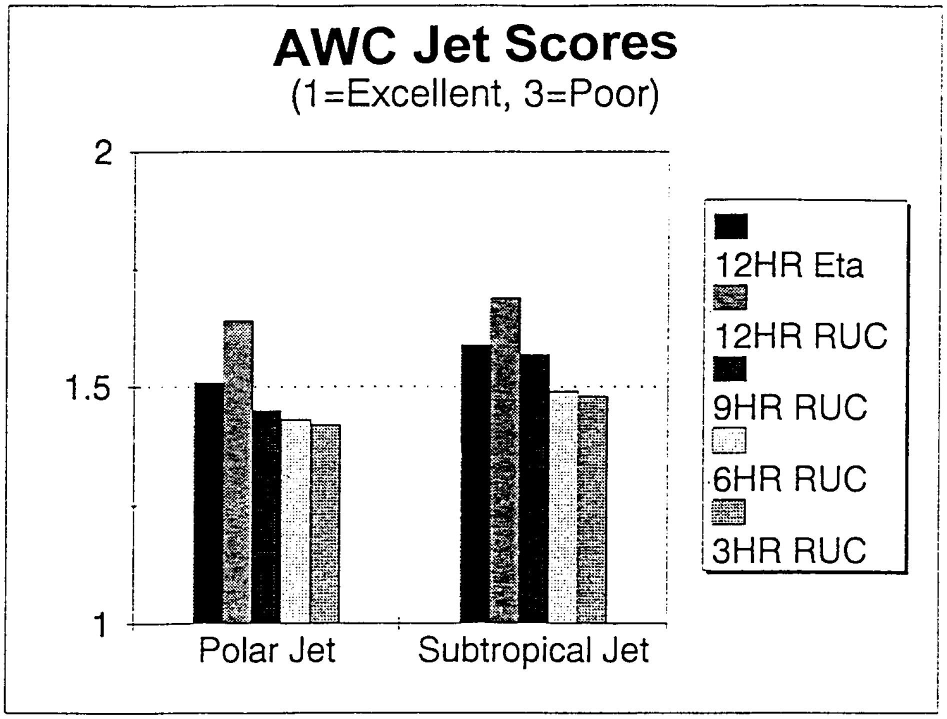


Figure 9. Average scores for forecasts of polar and subtropical jet stream speeds and positions given by NAWAU forecasters to RUC and Eta.

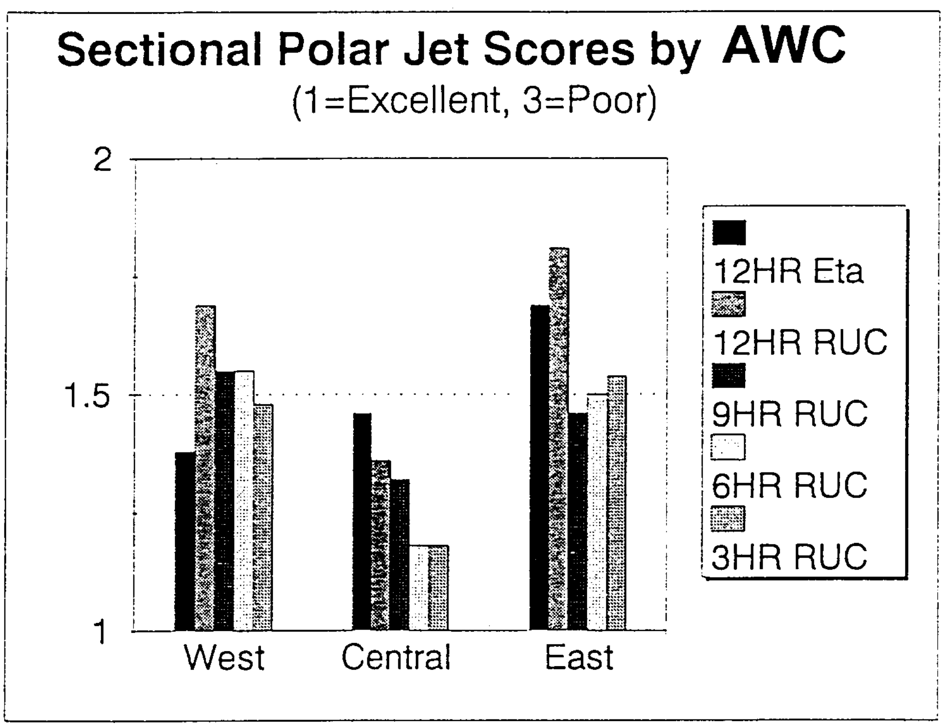


Figure 10. The performance as judged by AWC of the RUC and Eta by region in forecasting the polar jet.

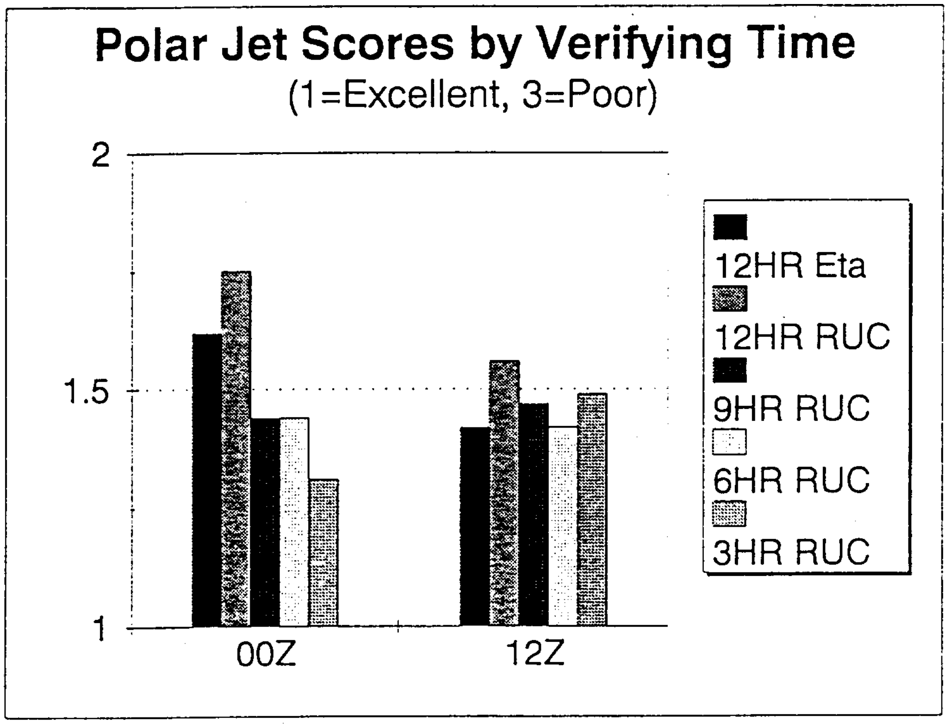


Figure 11. Polar jet forecast performance by time of day as judged by NAWAU.

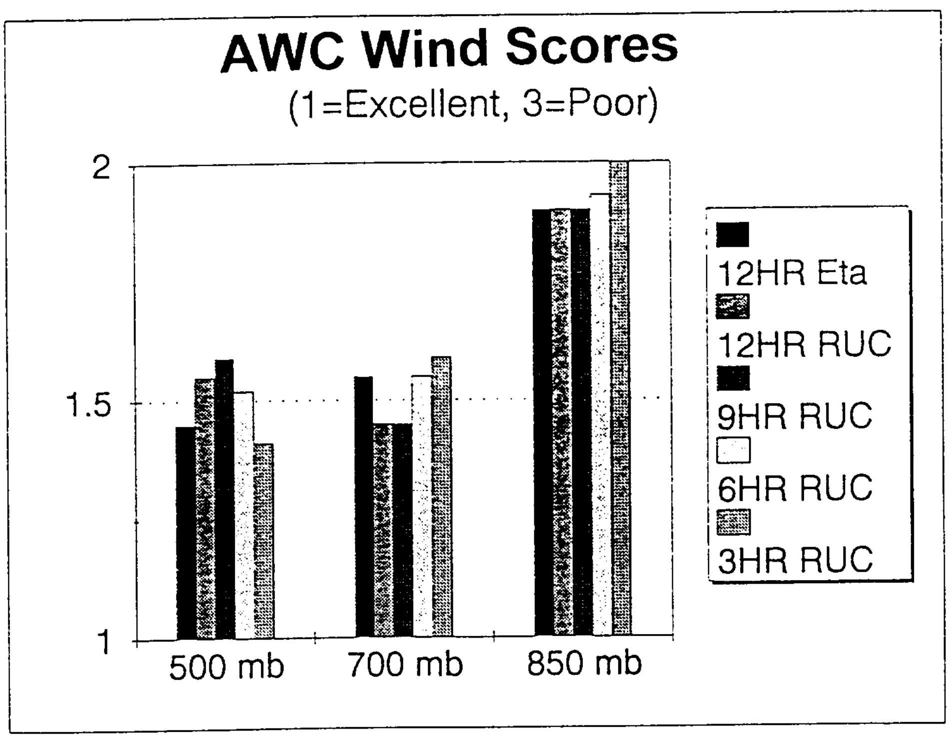


Figure 12. The performance as judged by AWC of the RUC and Eta by in forecasting mid-level winds.

RAPID UPDATE CYCLE SUBJECTIVE EVALUATION FORM

RUC VS ETA

NMC/MOD - Monitoring and Aviation Branch

VALID TIME 00 Z 27 MAR 94 EVALUATOR: ____________ ______

Please rank the Forecasts 1-5 where 1 is the best ranking and 5 is the worst. Rank the Analyses by placing a "+" in the column of the better analysis.

	Forecasts 12h Eta	12h RUC	9h RUC	6h RUC	3h RUC	Analyses 0h RUC	0h Eta
Arctic jet wind and position:	TIE ⟶					TIE	
Polar jet wind and position:	5	4	3	2	1	+	
Subtropical jet wind and position:	5	2	4	1	3	TIE	
Other Parameters (specify):							
______________________:							
Total Score:							

What is the 500mb flow regime? ✓ trof west, ridge east (TR); ___ ridge west, trof east (RT); ___ trof,ridge,trof (TRT); ✓ ridge, trof, ridge (RTR); ___ zonal (Z).

Remarks (include observed biases, special strengths and weaknesses; continue on back if you need more space):

"Polar Jet" Ruc did a much superior job with Max Winds ETA was terrible with a capital "T"

Figure 13. Example of the form used by MAB forecasters to evaluate the RUC.

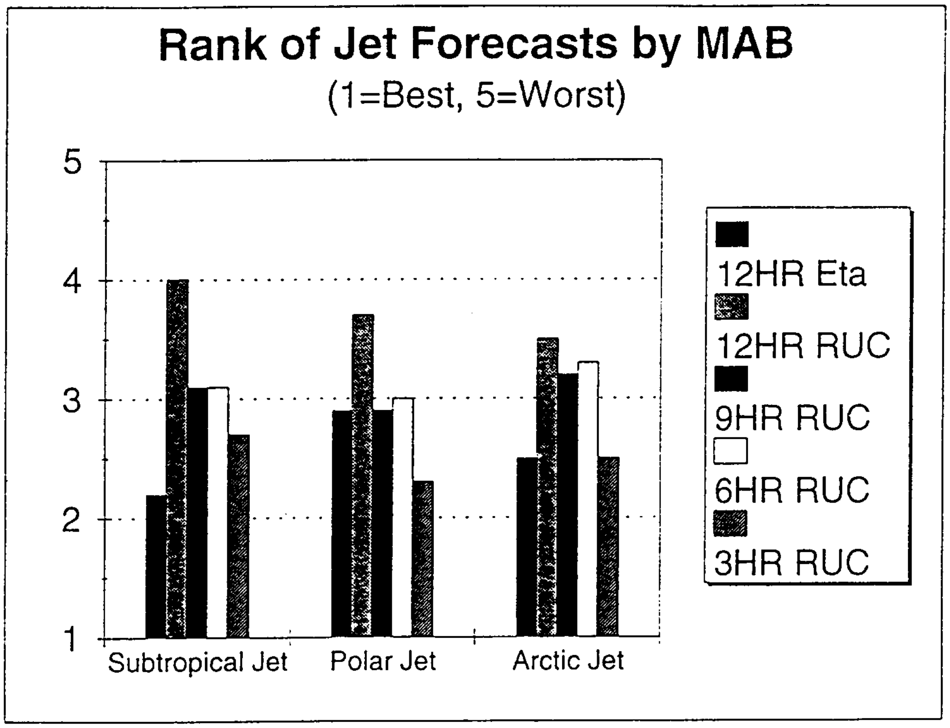


Figure 14. Average rankings awarded by MAB forecasters to RUC and Eta forecasts of the strength and position of the subtropical, polar, and arctic jets.